THE HAWAIIAN PLANTERS' RECORD

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A monthly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

Fiji Disease Gains Ground

Fiji disease has gained entrance to the Philippine Islands and is already established in several localities on Mindoro and Luzon. It has not been found on Negros up to the present time, and the Government is endeavoring to keep it out of that island by a strict quarantine.

The occurrence of Fiji disease in the Philippines greatly increases the chances of its eventually finding its way to Hawaii. We may rely upon our plant inspection service to intercept all canes coming by the usual routes; but there are unusual routes by which canes may arrive, and over these we can exercise no control.

It behooves us, therefore, to keep a sharp lookout for this disease, so that if it does reach our cane fields we shall detect it before it spreads to any extent, and so render its elimination possible.

Descriptions of Fiji disease sufficient for diagnosis may be found in early numbers of this magazine,* but in order to renew our impressions of this malady we are printing in this issue a brief description in which we combine the essential statements of our former articles and add some additional material.

Native Canes May Come Back

Some months ago, Messrs. Caum and Moir began a critical study of native canes. The necessity for this research was created by the keen interest being manifested in bud sports. Odd stools of cane are frequently found in fields of standard canes, and there is a tendency to view all such stools as bud sports of the standard variety which surrounds them. The majority of such odd stools, however, arise through the chance introduction of a cutting of some little known variety, and native canes are the most frequent interlopers of this sort. If we are going to correctly judge all such odd stools and recognize a bud sport when it does appear we must know all of the canes that can possibly gain entrance to our cultures.

* Planters' Record 3:200-202, and 4:330-332.

In their studies of the native canes Caum and Moir have brought to light some startling facts which may prove of far-reaching importance to the local sugar industry.

They have demonstrated that Striped Tip, Yellow Tip, and Yellow Bamboo are in reality native canes. These facts suggest a very interesting line of reasoning and a very promising line of experimentation. The canes mentioned have all made good records under adverse conditions where the cultivation of the better known varieties has proven unprofitable. Thus in Hamakua and Kohala, Striped and Yellow Tip have no equals as drought-resisting canes, and as high-land canes their excellence is recognized along the entire windward coast of Hawaii, while in the Pahala district Yellow Bamboo has been a successful competitor of Lahaina and Yellow Caledonia on fields of moderate to high elevation.

Does this not indicate that these native canes possess as inherent qualities certain sturdy characters which we are particularly anxious to bring out in some good canes at the present time? Drought resistance is a virtue much to be desired in any cane, while a variety suited to culture at high elevations is one of the immediate and pressing needs of the industry. Would it not be advisable, therefore, to test out all the available native canes in high-land nurseries; and at the same time employ the better varieties in our cane-breeding experiments?

Stubble Shaving.

ONOMEA SUGAR CO. EXPERIMENT NO. 10, 1921 CROP.*

SUMMARY.

The purpose of this experiment is to determine the value of stubble shaving towards increasing the yield of a field. The stubble shaving was accomplished by means of the implement modified from the Avery stool shaver by Mr. Silver.**

The cane involved was third ratoon, long. The stubble shaving was done on July 18, 1919, after which all plots were given uniform treatment by the plantation.

The result shows no increased yield of cane due to the stubble shaving. Slightly poorer juices from the shaved cane cause a slightly poorer yield of sugar than from the unshaved cane. Until we have more definite information regarding the effect of stubble shaving on the quality of the juices, we would be inclined to doubt the apparent loss of sugar due to stubble shaving. Following are the yields obtained:

* Experiment planned by W. P. Alexander and J. A. Verret.
Experiment laid out by W. L. S. Williams.

** See Record, Vol. XXI, p. 8.

Treatment	Yield—Tons per Acre		
	Cane	Q. R.	Sugar
No stubble shaving	41.5	7.44	5.58
Stubble shaving	41.6	7.79	5.34

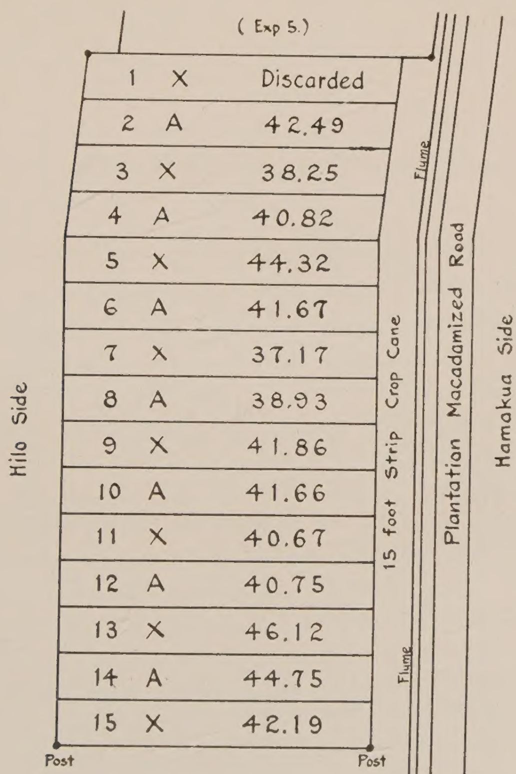
The following excerpts are taken from Mr. Williams' notes on the condition of the field at time of stubble shaving:

"This section of the field was not off-barred in 1917, but was hilled up quite high in 1918. Before harvesting the trash was burned and a second burning was applied before shaving the stubble. * * * The machine shaves from 2 to 3 inches from the top of the stools, cutting down all stumps and secondary growth (suckers). Sometimes high stools cause jamming of the machine, and delays, but this time serves to rest mules."

STUBBLE SHAVING

ONOMEA SUGAR CO. EXP. 10, 1921 CROP

Field 35.



Summary of Results

Plots	Treatment	Yields Per Acre		
		Cane	Q.R.	Sugar
A	Stubble Shaving	41.6	7.79	5.34
X	No Stubble Shaving	41.5	7.44	5.58

DETAILS OF EXPERIMENT.

Object:
To determine the value of stubble shaving with implement modified from the Avery stool shaver by Mr. Wm. Silver.

Location:
Field 35, makai of Experiment No. 5.

Crop:
Yellow Caledonia, third ratoon, long.

Layout:
No. plots: 15.
Size of plots: 1/10 acre each, consisting of 6 rows each 5.94 feet wide and 122.2 feet long.

Plan:
X plots—no stubble shaving.
A plots—stubble shaved.
Fertilization uniform to all plots and applied by the plantation.

Progress of Experiment:
July 18, 1919—Stubble shaved.
August 8, 1919—Fertilized 400 pounds B6 per acre.
November 20, 1919—Fertilized 400 pounds B6 per acre.
March 3, 1921—Experiment harvested by W. L. S. Williams.

R. S. T.

Lime Versus No Lime.

HILO SUGAR COMPANY EXPERIMENT NO. 18,* 1921 CROP.

This is an experiment to determine the value of lime and coral sand on acid soils. Comparison is made between 2000 pounds burned lime, 8000 pounds coral sand, 12,000 pounds burned lime, and nothing. The cane involved is Yellow Caledonia, fourth ratoons, long. The field was first offbarred, then the lime and sand applied in the kuakua. After applying, mule cultivators passed twice along each line, thoroughly mixing the lime and soil. All plots received uniform fertilization by the plantation.

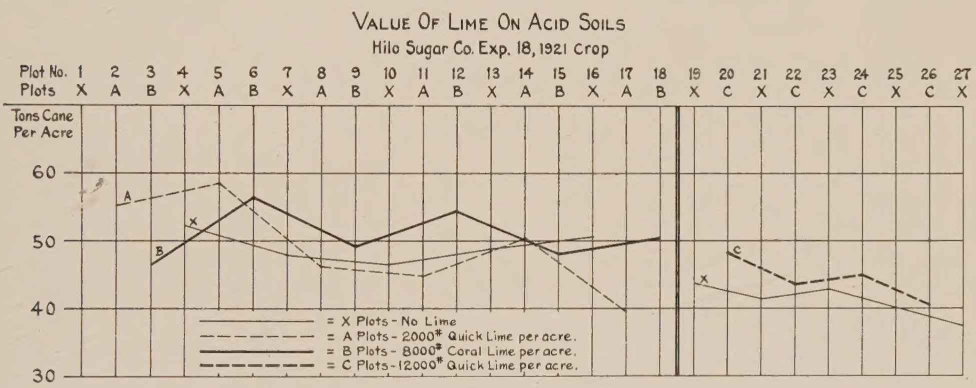
The results show that 12,000 pounds of lime produced a gain of 3.41 tons cane, while the 8000 pounds of sand and the 2000 pounds of lime showed practically no gain. The following tabulation shows the yields for the different treatments compared with the adjoining untreated plots:

Plot	Treatment	Tons Cane per Acre	Gain or Loss over Adjoining X Plots: Tons Cane per Acre
X (A & B)	0	49.26	0
A	2,000 lbs. lime	49.33	+ .07
B	8,000 lbs. sand	50.99	+ .73
X (C)	0	41.24	0
C	12,000 lbs. lime	44.65	+ 3.41

* Experiment planned by J. A. Verret and W. P. Alexander.
Experiment laid out by W. P. Alexander.
Experiment harvested by W. L. S. Williams.

The accompanying map shows the relative positions of the plots and also the individual plot yields.

An examination of the individual plot yields shows that the A, B, and adjacent X plots give considerably larger yields than do the C plots and their adjacent X plots, but this larger yield is due to some other factor than lime. In the case of the A, B, and adjacent X plots the yields are so irregular that no definite benefit from lime is noticeable, but in the case of the C plots and their adjacent X plots the difference between the C and X plots, though small, is consistent. This is clearly shown in the following curves:



This experimental area is to be plowed and planted and the experiment repeated on plant cane, using the same plots to note any residual effect the lime and sand may have on subsequent crops.

DETAILS OF EXPERIMENT.

Object:

To determine the value of applying lime and coral sand, comparing:

1. No lime or sand,
2. 2000 pounds burned lime,
3. 8000 pounds coral sand,
4. 12,000 pounds burned lime.

Location:

Field 20, along Amauula macadam road.

Crop:

Yellow Caledonia, fourth ratoons, long.

Layout:

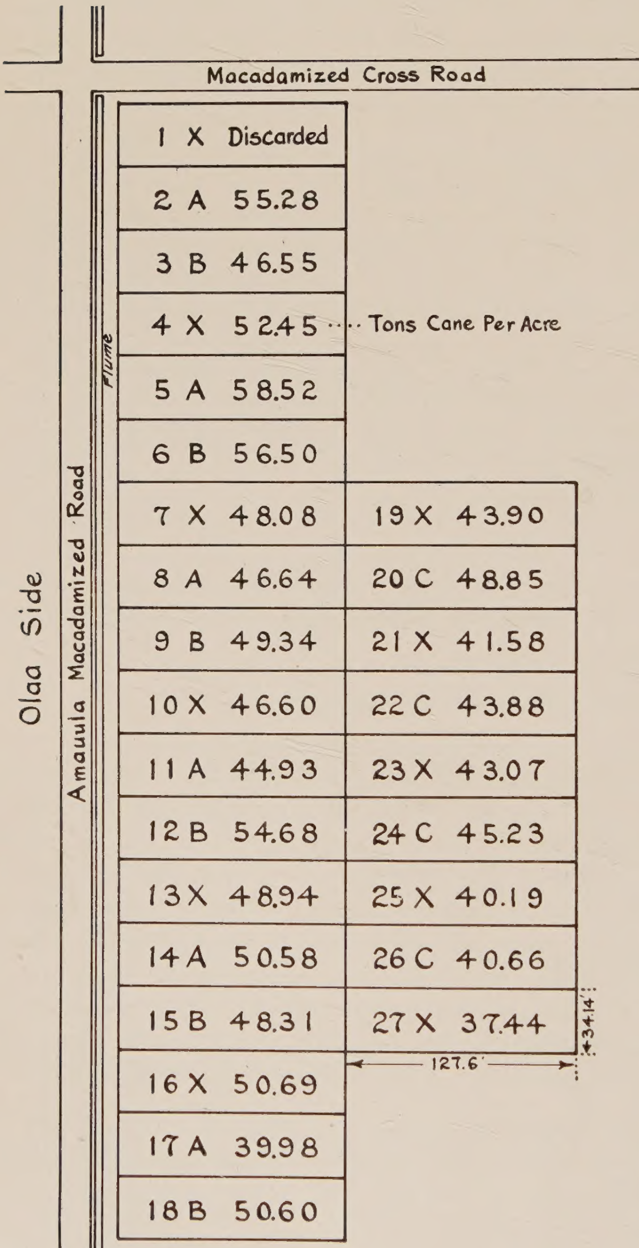
No. of plots: 27.

Size of plots: 1/10 acre each, consisting of six rows, each 5.69′x 127.6′. Rows 1 and 6 in each plot are guard rows to be discarded on harvesting, and rows 2, 3, 4, and 5 harvested as experiment.

VALUE OF LIME ON ACID SOILS

Hilo Sugar Co. Exp. #18, 1921 Crop

Field 30.



Summary of Results

Plots	No. of Plots	Treatment	Tons Cane Per Acre	Gain or Loss Over X Plots
X	6	No Lime	49.26	
A	6	2000# Quick Lime p.a.	49.33	+ 0.07
B	6	8000# Coral Lime p.a.	50.99	+ 1.73
X	5	Nothing	41.24	
C	4	12000# Quick Lime p.a.	44.65	+ 3.41

Plan:

Plots	No. of Plots	Treatment	Pounds per Acre
X	11	0	0
A	6	Burned lime	2,000
B	6	Coral sand	8,000
C	4	Burned lime	12,000

NOTE:—Analysis of top 10 inches of soil shows 5 tons of lime (CaO) are necessary to neutralize this soil.

Fertilization:

Uniform to all plots and to be applied by plantation as to surrounding field.

PROGRESS.

June 12, 1919—Offbarred.
June 14, 1919—Lime and sand applied.
July 2, 1919—Fertilized, 250 pounds C_2.
September 8, 1919—Fertilized, 375 pounds B_6.
January 20, 1921—Experiment harvested by W. L. S. Williams.

R. S. T.

Fertilizer—Forms of Nitrogen.

Grove Farm Experiment No. 1, 1921 Crop.*

In this experiment comparison is made between (A) inorganic nitrogen in several doses, (B) organic nitrogen in one dose, with a small spring dressing of nitrate of soda, and (C) no nitrogen, on second ratoons, long.

The cane yields of the organic and inorganic applications are identical, but better juices from the organic nitrogen give the sugar yields from those plots as 0.27 ton more than from the inorganic fertilization. It should be noted that the March and May fertilizations of the inorganic plots were combined and applied June first as nitrate of soda, making an application of 435 pounds nitrate of soda. This large application of fertilizer rather late in the season is probably responsible for the poor juices of these plots, and consequently for the apparently poorer yield from the inorganic nitrogen. The following tabulation shows the treatment and yields for this crop:

* Experiment originally planned by L. D. Larsen.

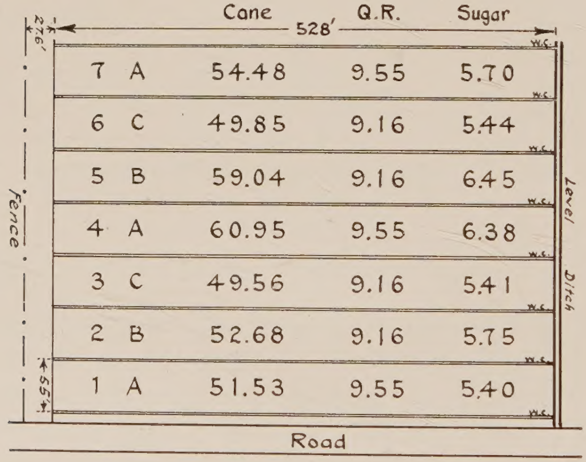
Plot	Fertilization in Pounds Nitrogen per Acre			Total Lbs. Nitrogen per Acre	Yields—Tons per Acre		
	Sept. 30, 1919	Feb. 6, 1920	June 1, 1920		Cane	Q. R.	Sugar
A (Inorg.)	36.75	36.75	67.50	141	55.65	9.55	5.83
B (Org.)	110.25	0	30.75	141	55.86	9.16	6.10
C (0)	0	0	0	0	49.70	9.16	5.43

Comparing now the yields of the organic and inorganic plots for the past three crops, we find that in plant cane the inorganic fertilizer gave considerably larger yields in both cane and sugar; in the first ratoons the yields in both cane

FORMS OF NITROGEN

GROVE FARM EXP. 1, 1921 CROP

Field 4.



Summary of Results

Plots	Treatment	Yields – Tons Per Acre		
		Cane	Q. R.	Sugar
A	Inorganic	55.65	9.55	5.85
B	Organic	55.85	9.16	6.10
C	0	49.70	9.16	5.43

and sugar were practically identical for both forms of nitrogen, and the total yield of cane and sugar for the three crops shows the inorganic nitrogen producing 6.09 tons cane or 0.59 ton sugar more than the organic nitrogen. The following tabulation shows the yields for each of the three crops and also the total yield of each treatment for the three crops:

Forms of Nitrogen	1917			1919			1921			Total for 3 Crops		
	Cane	Q. R.	Sug.	Cane	Q. R.	Sug.	Cane	Q. R.	Sug.	Cane	Q. R.	Sug.
Inorganic ...	50.89	8.57	5.94	36.5	8.25	4.42	55.65	9.55	5.83	143.04	8.83	16.19
Organic	44.19	8.80	5.02	36.9	8.20	4.48	55.86	9.16	6.10	136.95	8.77	15.60
None	49.37	9.13	5.41	36.2	7.93	4.57	49.70	9.16	5.43	135.27	8.78	15.41

As originally laid out for the plant crop, this experiment was designed to compare the Grove Farm method of fertilization with that generally recommended by the Experiment Station. The former practice was one application of organic nitrogen plowed into the soil before planting, while the latter practice was to apply nitrogen in three applications, during the growth of the crop, as soluble salts. After the plant crop the experiment was continued to compare organic and inorganic nitrogen.

The conclusion to be drawn from this experiment after harvesting three crops is that inorganic nitrogen is fully as effective as organic. As the former is the cheaper per unit, it would appear to be the preferable form.

Another phase of this experiment deserving consideration is the slight response of cane to nitrogenous fertilizer. During the plant and first ratoons, the yield of the fertilized and unfertilized plots, in both cane and sugar, was practically identical. In the second ratoon crop, after six years without the addition of nitrogen, the unfertilized plots show a loss in both cane and sugar. The following tabulation compares the average yield of all the fertilized and unfertilized plots for each of three crops:

	1917		1919		1921		Total Yield per Acre for 3 Crops	
	Cane	Sug.	Cane	Sug.	Cane	Sug.	Cane	Sug.
Fertilizer ...	47.54	5.48	36.7	4.45	55.75	5.96	139.99	15.89
No Fertilizer	49.37	5.41	36.2	4.57	49.70	5.43	135.27	15.41

Following are the average juice analyses for each treatment for the last crop:

Plot	Treatment	Brix	Pol.	Purity	Q. R.
A	Inorganic	17.30	14.26	82.43	9.55
B	Organic	17.66	14.76	83.58	9.16
C	No Nitrogen	17.38	14.70	84.58	9.16

DETAILS OF EXPERIMENT.

Object:

To compare organic nitrogen with nitrogen from inorganic salts.

Location:

Field 4.

Crop:

Yellow Caledonia, second ratoons, long.

Layout:

No. of plots: 7.

Size of plots: ⅔ acre (528′x 55′). Plots are separated from each other by water-courses which are straight and parallel. Cane lines are irregular.

Plan:

Plot	No. Plots	Form Nitrogen	Fertilization in Pounds Nitrogen per Acre				Total Lbs. N.
			Sept., '19	Jan., '20	Mar., '20	May, '20	
A	3	Inorganic	36.75	36.75	36.75	30.75	141
B	2	Organic	110.25	0	0	30.75	141
C	2	None	0	0	0	0	0

Inorganic nitrogen to be supplied by fertilizer mixture containing 11% N. (5% nitrate, 5% sulfate, 1% organic) and 9% phosphoric acid.

Organic nitrogen to be supplied by dried blood containing 12% N.

NOTE:—This experiment is a continuation of Experiment 1, 1917 and 1919 crops, which compares the Grove Farm practice of using organic nitrogen with the ordinary practice of using inorganic salts.

PROGRESS OF EXPERIMENT.

June 9-12, 1919—Last crop harvested.

September 6, 1919—This field was cut back. Since harvesting it has been offbarred, hilled up, and irrigated twice.

September 30, 1919—First fertilization as per schedule.

February 6, 1920—Second fertilization as per schedule.

June 1, 1920—Third and fourth fertilizations combined and applied today as N. S.

March 3, 1920—Experiment harvested by J. H. Midkiff. Calculations of cane yields and juice analysis made by A. H. Case.

R. S. T.

Native Canes on Molokai.*

By E. L. Caum and W. W. G. Moir.

In the course of our travels on Molokai, seven varieties of native canes new to us were found, names for four of them being obtained. In addition, further evidence that Striped Tip and Yellow Tip are native canes was obtained.

* From a report on an expedition to Molokai in search of native varieties of sugar cane.

Native cane in Kamakaipo Valley, Molokai.

On a trip to Kamakaipo Valley, on the west side of Molokai, a variety of cane, which is probably Ko Oliana, was found growing among the rocks under semi-arid conditions. In spite of a three years' drought that had burned the ranch pasturage, the cane had persisted, and when found had sticks three to four feet in length, with joints two to three inches long. Mr. J. G. Munro, manager of the Molokai Ranch, stated that to his personal knowledge the cane had been there for twenty years, and a Hawaiian of Kaunakakai, a man well over sixty years of age, remembered having seen it in his childhood. It is probably safe to say that this cane has been growing in those rock pockets, with no care

Native cane in Kamakaipo Valley, Molokai.

whatever, and with an average rainfall of about twenty inches, for at least forty years. It has been protected from cattle and deer by the great boulders. Two such rock pockets were found, about two hundred yards apart, and Mr. Munro said he knew of two or three others, a mile or more distant. In the very few notes on Hawaiian canes that we have found in the literature, the consensus of opinion seems to be that these varieties are all poor ratooners, but the evidence offered by these stools would seem to disprove this contention.

On a trip into Halawa Valley, on the east end of the island, the first cane seen was Striped Tip, and the second was Yellow Tip. The Hawaiian owner of the taro patch, on the banks of which the canes were growing, called the striped one Pakaweli, which is probably incorrect. He had no name for the yellow cane, but stated very distinctly that they were not haole canes. On the return trip, a cane similar to White Bamboo, under the name Opukea, was found behind a Hawaiian house at Waialua.

At Kaunakakai a number of native canes were found which were making a beautiful growth. Among them was Ko Palani, said to have been at one time the best known of Hawaiian canes. This was the first time we had seen the cane, after hunting for it over most of Maui, Oahu and Molokai, and parts of Hawaii.

An attempt was made, by sampan, to visit Pelekunu, Wailau and Papalaua valleys, in which the natives claimed there was considerable cane, but the roughness of the sea made it impossible to land.

The plantation or haole canes found in Hawaiian gardens on Molokai were Lahaina, Kenikeni, Cavengerie, Rose Bamboo, and Striped Mexican.

A crossing from Pukoo to Lahaina was made by sampan, and a day spent in visiting the native cane and bud-selection plantings at Hamakuapoko and Waikapu. At the latter place it was discovered that the Lahaina fields, of which the plantation is very proud, contained very little Lahaina cane, at least in the parts inspected, the majority of the stools being the native cane Opukea. This is especially true of the large stools which were being groomed for the next fair. Mr. Burns, the assistant manager, remarked that Mr. Penhallow had always said that Wailuku's Lahaina was different from, and apparently better than, Puunene's. It seems as though this might be explained by a closer inspection of the two plantations, which would possibly show that Puunene's Lahaina was Lahaina, while Wailuku's was mainly Opukea.

Fiji Disease.

By H. L. Lyon.

The one critical symptom by which Fiji disease may be recognized is the occurrence of elongated swellings or galls on the under surface of the leaves. These galls extend along the larger veins or vascular bundles and are, in fact,

formed by the abnormal growth of the tissues comprising these bundles (Figs. 1 and 2).

Galls are produced in similar manner in the vascular bundles of the stem and may be detected by splitting open the stick of an affected shoot.

Fig. 1. *Fiji Disease.* Portion of a cane leaf seen from below, showing the ridge-like galls along the veins.

Fig. 2. *Fiji Disease.* Two leaf galls enlarged twelve diameters.

Galls of this nature are not induced by any other known cane disease and consequently their presence on the leaves or in the stem of a cane plant may be accepted as conclusive evidence that that plant is afflicted with Fiji disease.

The most conspicuous symptom of Fiji disease to be noted in the field is a shortening and crumpling of the last leaves to unfold from the spindle (Figs. 3 and 4). This peculiarity will attract the attention when one is still a considerable distance from the affected cane. A diseased shoot may attain considerable length and be clothed with many healthy looking leaves of the usual length and color, but of a sudden it loses the power to produce normal leaves, throws out a few bent and twisted stumps and then ceases to grow altogether. Some of the eyes may start, but the resulting lalas soon repeat the antics of the main stem. The stick may remain alive for months or it may soon die.

When such a stick is examined the characteristic galls are usually to be found on most of the healthy-looking leaves which are not otherwise distorted and on all of the deformed, aborted leaves. These latter leaves look as though they had been burned or scalded before expanding, the injury destroying the upper half or two-thirds of the leaf blades, leaving short crumpled stumps (Figs. 4 and 5).

Fig. 3. *Fiji Disease.* A stool of Badila cane in the last throes of the disease. Photo by Mr. North.

As indicated above, this abortion and distortion of the young leaves marks the culmination of the disease in a shoot and the last efforts of the growing point to throw out leaves. A shoot may throw out leaf after leaf bearing galls, but otherwise normal, and grow on for months as though perfectly healthy; then of a sudden comes this final spasm in its growth, and it is done. The appearance of galls on the leaves is the first outward symptom by which the disease may be detected, but a cane may be hopelessly infected with it for months before any galls appear. The disease is therefore cumulative in the cane, the galls mark a well advanced stage of the disease, and the distortion of the apical leaves its final culmination.

No variety of cane has yet been found which is immune to Fiji disease. Some varieties will grow eighteen months or more after infection before any galls appear. On other varieties, however, the galls appear soon after infection and the final spasm quickly follows. Thus it is that some of the more susceptible varieties are unable to make any growth at all on soil containing the germs

Fig. 4. *Fiji Disease.* This stalk has made its final effort to throw out leaves. Photo by Mr. North.

of the disease. Lahaina, H 109, and D 1135 have proven very susceptible to the malady.

The very existence of the sugar industry of Fiji was at one time gravely threatened by this disease. At the present time the industry is thriving, with the disease quite under control. The planters of Fiji hold that this has been accom-

plished by employing resistant varieties and by selecting only healthy canes for seed; but their system of rotation has undoubtedly been a most important factor in effecting this control. Their general practice is to take but one ratoon crop and then to keep the land under beans for a year before again planting it to cane. Early in their experience with the malady they discovered that it rarely

Fig. 5. *Fiji Disease.* Distorted leaves from the tops of canes which had been overcome by the disease. Photo by Mr. North.

attacks cane growing on poor soil and consequently they find it expedient to take their seed from their poorest fields. In this way they obtain cuttings comparatively free from infection and the resulting stools are able to grow two years or more on the heaviest soils before the disease overtakes and destroys them.

In a recent letter Mr. D. S. North of the Colonial Sugar Refining Company states that Badila is still the standard variety in Fiji and that, up to the present time, they have not succeeded in finding a variety more resistant to Fiji disease.

During his recent sojourn in Fiji Mr. Pemberton wrote on Fiji disease as follows:

"As mentioned in a former letter, the Fiji disease is now completely under control in Fiji. I have discussed the plan of operation against this disease with many of the C. S. R. people and the independent planters. Their method has been universally the same and the results have been entirely successful everywhere. Should Fiji disease ever reach Hawaii, their successful experience in checking and almost eradicating it will be of great value to Hawaii through the adoption of the same methods. The results have been achieved entirely through seed selection.

Fig. 6. *Fiji Disease.* First ratoons at Nadi. The variety on the left is Childers Zigzag, a cane that has proven very resistant to the disease, while the variety on the right is Daniel Dupont, a cane that is very susceptible to the disease, but not easily killed out by it. Every stool of the Dupont was alive, but consisted of short leaves only, there being no sticks at all.

"The selection of seed for planting, free from outward evidences of Fiji disease, goes on as rigorously now as ever, though it is usually difficult to find stools affected by it. Specially experienced men pass along the rows and cut seed only from *stools* which show absolutely no signs of the disease. It is a matter of stool selection, rather than a selection of good sticks. Sometimes a vigorous stool will show one stick affected. The entire stool is left standing and goes to the mill to be ground, or, as on some estates, it is dug up and burned. This simple selection of seed from only healthy stools seems to have resulted in a complete control of the disease. I have been told by some of the independent planters that a brief laxity in such selection for a few seasons results in a quick ascendant return of the disease in all of the newly-planted fields.

"Mauritius bean, as a green manure, is as enthusiastically cultivated as ever, excepting at Nausori. The system of rotation described by Dr. Lyon in the June, 1911, issue of the *Planters' Record* is still scrupulously adhered to by all independent planters leasing land from the C. S. R. Company and on all C. S. R. cane land."

Fig. 7. *Fiji Disease.* Seventeen months plant cane affected with the disease. Of variety in foreground, every stool is dead. Of variety in background to left, 80% of stools are attacked, but too recently to be greatly damaged.

If Fiji disease ever appears on cane in Hawaii we shall no doubt detect it before it has spread to any extent, and take measures to completely eradicate it. Its general occurrence in Hawaii would undoubtedly compel us to abandon the culture of some of our favorite varieties such as Lahaina, H 109, and D 1135, and at the same time force us to replant our fields after taking one ratoon.

Phosphoric Acid Experiments at Hakalau.

The object of these experiments was to study the residual effects of phosphoric acid fertilization under conditions existing along the Hilo coast. These experiments involved the questions:

1. Does the application of phosphoric acid in addition to nitrogen increase yields?
2. If so, how much should be applied?
3. If so, what is the best form to apply?
4. If so, is raw rock phosphate in one large dose, enough to last four crops, more profitable than an equal money value of phosphoric acid as reverted phosphate applied one-fourth to each of four crops?

This series of experiments was harvested in 1919[1] as plant cane. For that crop the results were negative. That is, the omission of phosphoric acid did not in any way cause a reduction in yields, or conversely, the addition of phosphoric acid did not increase either the yield of cane or sugar. It was considered essential, however, that these experiments be repeated to note the residual effect of these phosphoric acid applications.

Now, again, the combined results of these experiments give a negative response. Cane which has received nitrogen but no phosphoric acid for four years has produced as large crops as has that receiving both nitrogen and phosphoric acid. Varying the amount of phosphoric acid from 100 pounds per acre to 400 pounds per acre caused no increase in yield, while applying phosphoric acid in various forms has produced no effect. The money expended in the purchase and application of phosphoric acid, under these conditions, has not been returned by any increase of yield during the plant and first ratoon crop.

HAKALAU EXPERIMENT NO. 4, 1921 CROP.*

SUMMARY.

This was a comparison of 100 pounds of phosphoric acid applied as:

A. Reverted phosphate;
B. Raw rock phosphate;
C. Acid phosphate;
X. No phosphate.

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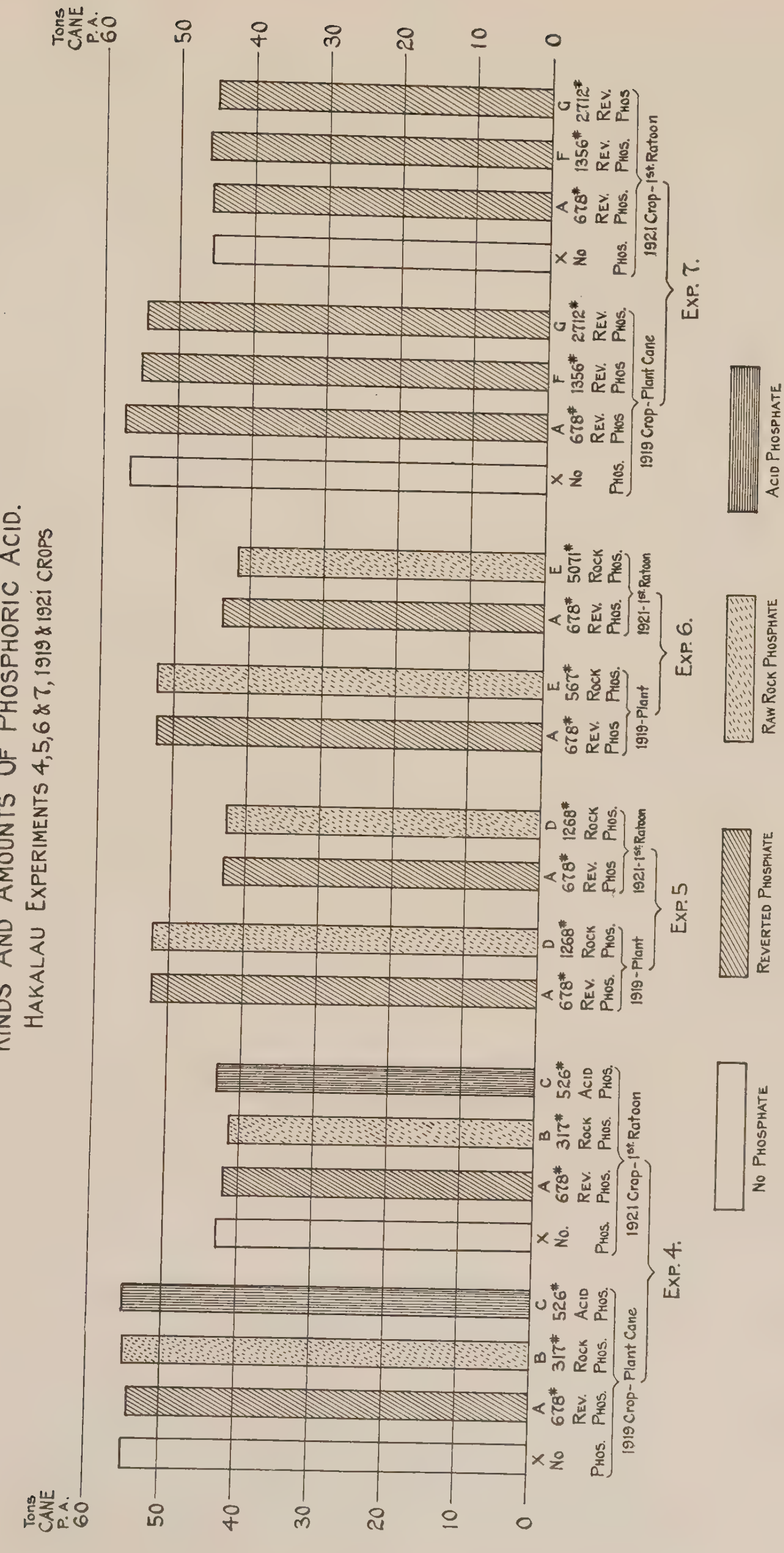
1 Reported in Record, Vol. XXI, p. 72.

* Experiment originally planned by L. D. Larsen.
Experiment laid out by W. P. Alexander and J. S. B. Pratt, Jr.
Experiment harvested by W. L. S. Williams.

Kinds And Amounts Of Phosphoric Acid.

Hakalau Experiments 4, 5, 6 & 7, 1919 & 1921 Crops



KINDS AND AMOUNTS OF PHOSPHORIC ACID

HAKALAU EXPERIMENTS 4, 5, 6 & 7, 1919 & 1921 CROPS

Plan Showing The Relative Positions Of The Experiments And Plots, One To Another And Plot Yields For 1921 Crop

Plots	Exp. 7		Exp. 6.	Exp. 5.	Exp. 4.	
1	X 55.99	F 43.99	E 45.77	A 39.51	X 45.11	A 45.09
2	A 60.75	G 41.78	A 43.52	D 35.32	C 47.95	X 46.74
3	F 60.57	X 39.88	E 44.16	A 43.46	X 39.45	B 44.58
4	G 58.86	A 41.43	A 43.60	D 41.92	A 39.89	X 46.93
5	X 52.96	F 47.86	E 43.08	A 45.47	X 40.37	C 40.13
6	A 41.94	G 36.59	A 39.91	D 45.56	B 45.50	X 46.29
7	F 43.25	X 40.81	E 38.25	A 41.70	X 43.82	A 39.95
8	G 50.73	A 40.98	A 41.23	D 39.48	C 45.92	X 39.49
9	X 50.57	F 36.71	E 37.44	A 37.15	X 38.58	B 37.73
10	A 55.40	G 44.40	A 42.97	D 41.35	A 40.12	X 35.73
11	F 52.93	X 39.98	E 38.74	A 39.60	X 42.82	C 38.16
12	G 49.86	A 36.86	A 38.80	D 38.36	B 38.83	X 43.96
13	X 46.09	F 40.52	E 38.17	A 42.92	X 40.50	A 43.15
14	A 44.08	G 40.21	A 43.22	D 44.29	C 44.26	X 40.76
15	F 39.00	X 43.97	E 37.35	A 47.71	X 48.96	B 41.97
16	G 36.39	A 44.87	A 46.72	D 46.18	A 45.38	X 43.62
17	X 40.00	F 50.11	E 50.59	A 47.97	X 45.81	C 44.25
18	A 45.89	G 42.75	A 46.38	D 42.34	B 36.54	X 43.53
19	F 49.32	X 46.91	E 43.66	A 42.87	X 42.75	A 44.51
20	G 51.24	A 45.59	A 45.32	D 44.37	C 42.05	X 39.10
21	X 48.37	F 46.60	E 41.85	A 41.73	X 41.11	B 41.61
22	A 48.68	G 44.67	A 47.71	D 46.00	A 39.86	X 48.41
23	F 44.97	X 44.02	E 42.99	A 46.83	X 45.27	C 43.97
24	G 46.23	A 45.99	A 45.23	D 48.14	B 45.22	X 40.13

Summary of Results (Exp. 7.)

Plots	Treatment	Cane Yields - Tons Per Acre. 1919-Plant Cane	1921-1st Ratoon
X	No Phosphate	56.65	45.79
A	678# Rev. Phos.	57.32	46.04
F	1356# Rev. Phos.	55.19	46.32
G	2712# Rev. Phos.	54.49	45.31

Summary of Results (Exp. 6.)

Plots	Treatment	Cane Yields - Tons Per Acre 1919-Plant Cane	1921-1st Ratoon
A	678# Rev. Phos.	52.43	43.72
E	5071# Rock Phos.	52.54	41.84

Summary of Results (Exp. 5.)

Plots	Treatment	Cane Yields - Tons Per Acre 1919-Plant Cane	1921-1st Ratoon
A	678# Rev. Phos.	52.37	43.08
D	1268# Rock Phos.	52.37	42.78

Summary of Results (Exp. 4.)

Plots	Treatment	Cane Yields - Tons Per Acre. 1919-Plant Cane	1921-1st Ratoon
X	No Phosphate	55.20	42.89
A	678# Rev. Phos.	54.50	42.24
B	317# Rock Phos.	55.20	41.50
C	526# Acid Phos.	55.40	43.33

The phosphates were applied in the furrow before planting. For the present crop all plots received a uniform dose of 1200 pounds nitrate of soda applied in four equal doses. The following tabulation shows the treatment and yield in cane for this crop and the total yield in cane for the past two crops, plant and first ratoon:

Plot	Treatment	Yields—Tons per Acre	
		First Ratoon	Plant and First Ratoon
A	Reverted phosphate ..	42.24	96.74
B	Raw rock phosphate ..	41.50	96.70
C	Acid phosphate	43.33	98.73
X	No phosphate	42.88	98.08

The average yield for the two crops of the three kinds of phosphate is 97.39 tons cane, while that for no phosphate is 98.08 tons cane per acre. This shows that cane in this district does not respond to phosphoric acid.

DETAILS OF EXPERIMENT.

Object:

1. To test the residual fertilizing value of phosphoric acid in various forms.
2. To compare equal amounts of phosphoric acid applied as:
   - A. Reverted phosphate,
   - B. Raw rock phosphate,
   - C. Acid phosphate.

Location:

Field 10.

Crop:

Yellow Caledonia, plant cane.

Layout:

No. of plots: 48.
Size of plots: 1/10 acre each, consisting of 6 lines, each line 5.65 feet wide and 128.3 feet long.

Plan:

Plot	No. Plots	Phosphate—Pounds per Acre*	Pounds P_2O_5 per Acre
A	8	678 reverted phosphate (14.73%).....	100
B	8	317 raw rock phosphate (31.55%).....	100
C	8	526 acid phosphate (19%)...........	100
X	24	0	

* Applied in furrow to previous crop before planting.

Fertilization:

	Pounds Nitrate of Soda per Acre				Total Pounds Nitrogen
	Aug., 1919	Oct., 1919	Jan., 1920	Apr., 1920	
All Plots ...	300	300	300	300	186

PROGRESS OF EXPERIMENT.

June 25, 1919—Experiment off-barred.
August 19, 1919—Fertilized, 300 pounds N. S. per acre.
October 6, 1919—Fertilized, 300 pounds N. S. per acre.
January 16, 1920—Fertilized, 300 pounds N. S. per acre.
April 13, 1920—Fertilized, 300 pounds N. S. per acre.
January 25-February 7, 1921—Experiment harvested by W. L. S. Williams.

HAKALAU EXPERIMENTS 5 AND 6,** 1921 CROP.

These two experiments dealing with reverted and raw rock phosphate are so closely related that they are summarized together.

In Experiment No. 5, comparison is made between the residual values of phosphoric acid applied in equal money values as reverted and raw rock phosphate. The phosphates were applied in the furrow to the previous crop before planting. The fertilization of the present crop was uniform to all plots, consisting of 1200 pounds nitrate of soda applied in four equal doses. The following tabulation shows the yields of cane for this crop and the total yield of cane for the two crops, plant and first ratoon:

Plot	Treatment	Yields in Tons Cane per Acre	
		First Ratoon	Plant and First Ratoon
A	678 lbs. reverted phosphate...	43.08	95.45
D	1268 lbs. raw rock phosphate...	42.78	95.15

In Experiment 6, comparison is made between the residual effect of phosphoric acid applied in one large dose as raw rock phosphate to last four crops, with an equal money value of phosphoric acid as reverted phosphate, one-fourth applied with each of four crops. The raw rock phosphate was applied in the furrow before planting, while one-fourth the reverted phosphate was applied to the plant crop and one-fourth to the present crop. Fertilization to this crop was uniform to all plots, consisting of 1200 pounds nitrate of soda applied in four equal doses. The following tabulation shows the yields of cane for this crop and the total yield of cane for the two crops, plant and first ratoon:

** Experiment originally planned by L. D. Larsen.
Experiment laid out by W. P. Alexander and J. S. B. Pratt, Jr.

Plot	Treatment	Pounds P_2O_5 per Acre	Cane Yields—Tons per Acre	
			First Ratoon	Plant and First Ratoon
A	678 lbs. reverted phosphate..	100	43.72	96.15
E	5071 lbs. raw rock phosphate..	1600	41.84	94.38

NOTE:—The A plots have to date received 200 pounds phosphoric acid, half to each crop.

DETAILED ACCOUNT, EXPERIMENT 5.

Object:

To compare residual effect of equal money values of reverted and raw rock phosphate.

Location:

Field 10.

Layout:

No. of plots: 24.
Size of plots: 1/10 acre each, consisting of 6 lines, each 5.65 feet wide and 128.3 feet long.

Crop:

Yellow Caledonia, first ratoons, long.

Plan:

Plot	No. Plots	Pounds Phosphate per Acre*	Pounds P_2O_5 per Acre
A	12	678 lbs. reverted phosphate (14.73%)..	100
D	12	1268 lbs. raw rock phosphate (31.55%)..	400

* Applied in furrow before planting.

Fertilization uniform to all plots, as follows:

	Pounds Nitrate of Soda per Acre				Total Pounds Nitrogen
	Aug., 1919	Oct., 1919	Jan., 1920	Apr., 1920	
All Plots ...	300	300	300	300	186

PROGRESS OF EXPERIMENT 5.

May, 1919—Previous crop harvested.
June 25, 1919—Experiment off-barred.
August 19, 1919—First fertilization, 300 pounds N. S. per acre.
October 7, 1919—Second fertilization, 300 pounds N. S. per acre.
January 16, 1920—Third fertilization, 300 pounds N. S. per acre.
April 13, 1920—Fourth fertilization, 300 pounds N. S. per acre.
January 25-February 3, 1921—Experiment harvested by W. L. S. Williams.

DETAILED ACCOUNT, EXPERIMENT 6.

Object:

To compare the value of phosphoric acid applied in one large dose as raw rock phosphate, to last four crops, with an equal money value of phosphoric acid as reverted phosphate, one-fourth to each of four crops.

Location:

Field 10.

Layout:

No. of plots: 24.

Size of plots: 1/10 acre each, consisting of 6 lines, each 5.65 feet wide and 128.3 feet long.

Crop:

Yellow Caledonia, first ratoons.

Plan:

Plot	No. Plots	Pounds Phosphate per Acre	Pounds P_2O_5 per Acre
A	12	678 lbs. reverted phosphate (14.72%)..	100
E	12	5071 lbs. raw rock phosphate (31.55%)..	1600

NOTE:—Reverted phosphate applied to each crop; raw rock applied to plant cane in furrow before planting.

Fertilization:

	Pounds Nitrate of Soda per Acre				Total Pounds Nitrogen per Acre
	Aug., 1919	Oct., 1919	Jan., 1920	Apr., 1920	
All Plots ..	300	300	300	300	186

PROGRESS OF EXPERIMENT.

May, 1919—Previous crop harvested.
June 25, 1919—Experiment off-barred.
August 20, 1919—First fertilization, 300 pounds N. S. per acre.
August 25, 1919—A plots received 678 pounds reverted phosphate per acre.
October 6, 1919—Second fertilization, 300 pounds N. S. per acre.
January 17, 1920—Third fertilization, 300 pounds N. S. per acre.
April 14, 1920—Fourth fertilization, 300 pounds N. S. per acre.
January 25-February 3, 1921—Experiment harvested by W. L. S. Williams.

HAKALAU EXPERIMENT 7, 1921 CROP.*

SUMMARY.

This experiment is one testing the residual effect of phosphoric acid applied at the rate of 0, 100 pounds, 200 pounds, and 400 pounds per acre as reverted phosphate. The phosphate was applied in the furrow before planting. Fertili-

* Experiment originally planned by L. D. Larsen.
Experiment laid out by W. P. Alexander and J. S. B. Pratt, Jr.

zation of the present crop has been uniform to all plots, consisting of 1200 pounds of nitrate of soda in four equal doses. The following tabulation shows the cane yields for this crop and the combined yields for the 1919 and 1921 crops:

Plot	Treatment in Pounds Reverted Phosphate per Acre	Cane Yields in Tons per Acre	
		First Ratoon	Plant and First Ratoon
A	678	46.04	103.36
F	1356	46.32	101.51
G	2712	45.31	99.80
X	0	45.79	102.44

The conclusions to be drawn from this experiment are that the cost of the phosphate and its application has not been compensated for by any increase in yield.

DETAILS OF EXPERIMENT.

Object:

To compare 0, 100, 200, and 400 pounds phosphoric acid.

Location:

Field 10.

Crop:

Yellow Caledonia, first ratoons, long.

Layout:

No. of plots: 48.

Size of plots: 1/10 acre each, consisting of 6 lines, each 5.65 feet wide and 128.3 feet long.

Plan:

Plot	No. Plots	Pounds Reverted Phosphate per Acre*	Pounds P_2O_5 per Acre
A	12	678	100
F	12	1356	200
G	12	2712	400
X	12	0	0

* Applied in furrow before planting.

Fertilization:

	Pounds Nitrate of Soda per Acre				Total Pounds Nitrate Soda per Acre
	Aug., 1919	Oct., 1919	Jan., 1920	Apr., 1920	
All Plots ...	300	300	300	300	186

PROGRESS OF EXPERIMENT.

May, 1919—Last crop harvested.
June 25, 1919—Experiment off-barred.
August 20, 1919—First fertilization, 300 pounds N. S. per acre.
October 6, 1919—Second fertilization, 300 pounds N. S. per acre.
January 17, 1920—Third fertilization, 300 pounds N. S. per acre.
April 14, 1920—Fourth fertilization, 300 pounds N. S. per acre.
January 25-February 2, 1921—Experiment harvested by W. L. S. Williams.

R. S. T.

The Economical Use of Irrigation Water.*

By Guy R. Stewart.

A considerable number of our Hawaiian plantations depend entirely upon irrigation water to raise any sort of successful cane crops. An equally large group rely principally upon the annual rainfall. Some of the lower fields may be irrigated on the latter plantations, but the principal use made of ditch water in ordinary years is to flume the cane down to the mill. Extraordinary years, with light rainfall, come everywhere, even in the Hawaiian Islands. The past dry years have shown there is no such thing as dependable rains. Many a plantation has figured this last year on the extra use that might be made of the flume water after it left the loading stations or the mill. There are a few places, which have never irrigated before, that are now planning to contour their lower fields when they replant them, so the crop could be carried through another dry spell. Such a year as the past one has made everyone unusually interested in getting everything that is possible out of all the water on the plantation.

The economical use of water not only consists of getting it onto the fields that are suffering in a dry spell, but also in making the most of the regular supply on the irrigated plantations. The same simple principles apply in either case. The first thing to be considered in the economical operation of any ditch system is, how large is the transmission loss. That is to say, what per cent of the water that leaves the pump head, or the ditch intake, finally gets into the watercourses in the cane fields. Every plantation ought to know just how much water disappears along the way.

The only sure method of checking up on this loss is by accurately measuring the water where it enters the system, then measuring it again into the main distributing ditches, and finally into the field laterals. If the per cent of loss from seepage is at all high, the main ditches and laterals can be given a concrete surface. This seepage loss will depend largely upon the nature of the soil and subsoil, and also on the length of time the ditch has been in operation. In soils that are inclined to silt, or puddle, the loss will decrease as the ditches are used. If the water has to be transported many miles, it has generally been found that the loss is sufficient to pay for surfacing the ditches.

* A lecture delivered at the Short Course for Plantation Men, University of Hawaii, October, 1920.

Water Measurement.

There are several systems of units used for expressing the flow of a stream, or the head of water developed by a pump. These units are easily changed from one system to another, as indicated in the following brief table of the more important values:

Table of Water Measurement.

1 cubic foot = 7.5 gallons (7.48 exact).
1 acre foot = 43,560 acre feet = 323,136 gallons.
1 second foot = 7.5 gallons per second = 450 gallons per minute.
1 second foot in 24 hours gives nearly 2 acre feet (1.983 exact).
1 second foot in 1 hour gives nearly one acre inch.
1 second foot is equivalent to 40 miner's inches (controlled by a 6-inch pressure head).

If we know the daily discharge of a pump in gallons, we can readily change the figure to acre feet by dividing by 323,136, or to second feet by dividing the flow per minute by 450.

It will be seen in the above table that there are really four methods of water measurement. These are: to state the amount in gallons; in cubic feet per second; in acre feet; or in miner's inches. The expression in acre inches or acre feet is generally used for the amount of water applied to land, as it immediately indicates how heavy the irrigation will be when spread over the field. Stream flow is usually given in terms of cubic feet per second.

The entire question of stream measurement is too extensive to be dealt with here in great detail. The theory underlying the operations is extremely simple, but various precautions must be observed in order to obtain accurate results. If we have a flume 12 inches wide carrying water to the depth of 12 inches, placed on such a grade that the water flows at the rate of 1 lineal foot per second, this will give a flow of 1 cubic foot per second. That is to say, the cross-section of a flume or ditch, multiplied by the velocity in feet per second, gives the flow in cubic feet per second.

In open streams it is necessary to have a gauging station where the vertical area across the stream is measured and the velocity of the current determined by a current meter or float. The most usual method of measuring the flow of a ditch is by one of the standard weirs, which are essentially boxes through which the water flows with a constant head. Tables are made up for various forms of weirs which you can find in engineering handbooks or reference books on irrigation.

Soil Moisture.

Let us now suppose that the ditch water has been delivered to the field with the smallest possible loss. Probably most field men have observed that the seepage loss from the field laterals is reduced by using as large a stream as the men can conveniently handle. There is no surer way to lose water than to divide up the irrigation head so that each man works separately with a small stream in a different part of the field.

We now have the water applied to the actual soil, and it will be well to refer

again to some of the things you have already heard about soil moisture. Water may exist in the soil in three different ways. First, all soil contains hygroscopic moisture. This is the moisture that stays in the soil even when it appears to be dry as dust. It is ordinarily determined by exposing a thin layer of soil to air that is saturated with moisture. In this way we find the greatest possible hygroscopic capacity of the soil. The most important type of moisture for plants is the second form, which we call capillary moisture. This water is the thin film which is held around the soil particles.

If we place a small glass tube of about ⅛-inch bore in a tumbler of water, we find the water will rise a fraction of an inch in height above the surface of the tumbler. If the tube is of extremely small bore, about as large as a coarse hair, the water will rise several inches in height. This same force of capillarity carries water in soils from one particle to another either up or down. Just as with the tube, the smaller the openings are, the higher the water will rise. In a coarse sand, water rises quickly for a short distance, while in a fine silt loam it will ascend a number of feet, but will require several days to do this.

As more water is applied to soil, the capillary moisture increases till we reach the maximum moisture-holding capacity. We then have free water flowing through the soil. If this continues, and the drainage capacity is not equal to the amount put on, we drive the air out of the soil and it becomes waterlogged. It has been found that the optimum moisture content for most soils is forty to sixty per cent of the maximum water-holding capacity. We should never add sufficient moisture to bring the water in the whole soil mass greatly above the optimum for any length of time.

Verret and Allen found that one inch of rain or irrigation would wet the soil at the Waipio Substation down to a depth of 10 to 12 inches. The soil there will retain all except 3% of a 2-inch irrigation, 47% of a 6-inch irrigation, and 65% of a 9-inch irrigation. This shows the great loss of water there is from one irrigation on a typical silty clay soil.

A number of interesting experiments have been made at various places in the United States to try and discover what part of the water held in the soil can be used by the plant. These studies were made by growing small plants in pots sealed over with soft wax to prevent surface evaporation. The plants were allowed to grow until they wilted. They were then put in a chamber with moist air to see if they would revive. If the plants remained wilted, this was called the wilting point, and the per cent of moisture remaining in the soil was called the wilting coefficient of that soil. In general, it has been found that the hygroscopic moisture is slightly lower than the wilting coefficient.

Some of the relationships of the various physical constants are shown in the following table. The figures given are the average of a number of determinations, and in the case of the mainland soils it shows the increase in moisture-holding capacity that is caused by finer texture and larger amounts of clay. A large part of our Hawaiian soils would be classed as clays or silty clay loams, and possess a remarkable capacity for holding water. Organic matter also increases a soil's power to hold moisture, and many Island soils owe part of their moisture-holding capacity to a high content of decomposed vegetable matter.

RELATION OF PHYSICAL CONSTANTS OF SOILS.

	Hygroscopic Coefficient	Wilting Coefficient	Optimum Moisture	Maximum Moisture-Holding Capacity
Mainland Soils:				
Coarse sand	0.5	0.9	13.8	23.2
Fine sand	1.5	2.6	17.9	29.9
Sandy loam	3.5	4.8	26.9	44.9
Loam	9.8	13.9	33.3	55.9
Clay loam	11.8	14.6	32.5	54.2
Hawaiian Soils:				
Onomea Plantation	21.4	...	49.2	82.2
Pepeekeo Plantation	21.6	...	53.9	89.9
Hamakua Plantation	22.3	...	60.0	100.2
Honokaa Plantation	22.6	...	53.0	89.1
Hawi Mill	17.1	...	36.0	60.0
Hawaiian Sugar Co.	16.8	...	34.0	57.7
Lihue and Grove Farm ...	19.7	...	36.6	61.5
Kilauea	19.4	...	36.0	60.0

Field Applications.

We see that the useful moisture for the plant lies between the wilting point of the soil and the optimum moisture capacity. If we greatly exceed the optimum we destroy the soil's aeration and also waste a large amount of irrigation water. It has been found that practically all plants grow best if the soil is kept reasonably close to its optimum content of moisture during the early part of the plant's growth. Most grain crops ripen best if the moisture is reduced in the soil for a few weeks before harvesting, thus forcing the plant to complete maturity. This has also been found to be the case with sugar cane.

In field work, then, our greatest economy will be obtained in the use of irrigation water, if we irrigate frequently enough to keep the soil close to the optimum when the cane is making its heaviest growth. We must avoid adding water in such quantity that there will be a large underground run-off and the lower soil possibly waterlogged. Evidently the different soils on the same plantation will be found to vary considerably in their water requirements. Here is where soil augers in the hands of the field men will be found of great value. Anyone who goes through a cane field can easily see whether the soil is dry enough for the cane to wilt, but it takes an actual boring down into the subsoil to see whether the soil is up to optimum moisture content or over it.

The optimum moisture content of a soil can soon be recognized simply by feeling the soil brought up by the auger. Everyone who has plowed land knows the point at which the soil works the best and turns a perfect furrow. This point of ideal working for plowing or spading is slightly below the optimum moisture content. Soil which forms a pasty mass when the borings are taken out of the auger is above the optimum content and not far from the point where free water can be pressed out. A little experience in the field with an auger

making borings to a depth of two to four feet will soon develop very definite knowledge about the fields of any plantation.

It is a good plan to make several borings before a field is irrigated and then check the moisture condition of the soil by boring at intervals of a few days until the field is irrigated again. In this way the men handling the irrigating gangs will soon learn how much water their fields actually require. They will frequently find some areas that dry out more rapidly than the balance of the field. The addition of mud press or stable manure, if the spots are not too large, will generally improve the water-holding capacity and allow them to irrigate the field only when the whole area requires water.

Report of Committee on Juice Deterioration.*

By W. R. McAllep.

Your Committee on Juice Deterioration has the following report to make:

Contributions on the subject of the deterioration of juice in the settling tanks when the juice is kept over night or over the week end have been received from Mr. V. P. Iyer, Mr. A. Fries, Mr. H. L. White, and Mr. H. S. Walker.

We will present Mr. Iyer's paper first.

"During the latter part of the season at Waiakea Mill Co., we worked during the day only. Conditions compelled us to leave all the juices in mixed juice measuring tanks, settling tanks, and the evaporator juice supply tanks, as soon as the mill stopped grinding in the evening, till next day. The curiosity to see if there were any, and if so, how much deterioration took place in leaving the juices and syrup at the end of the week during the time when there were two shifts, led us to make frequent tests which were done throughout the crop. The analyses of these are as follows, arranged according to the order in which they were performed. In order that the analyses may not be influenced by autosuggestion and preconceived conclusions, the corrected Brix, % polarization, and purity were calculated after the tests were made.

Mr. W. R. McAllep of the Experiment Station during his visit of inspection to the mill recommended that the juice in the juice heater be kept at a lower temperature for an hour before the mill stopped grinding for the day, according to the results of Mr. Walker's investigations at Pioneer Mill last year. This advice was followed throughout the balance of the crop during which tests No. 16 to No. 34 were performed."

The individual tests are omitted, but a summary by Mr. Iyer follows:

Test No.	Time Standing	Temperature, Initial – Final	Drop in Purity	Remarks
5	9½		1.65	No preservative.
8	10¼		1.42	No preservative.
16-18	9-12		1.80	No preservative.
19	11¼	198 – 162	0.71	No preservative.
20-23	11½	188 – 174	0.25	No preservative.
11	12½	Ordinary routine	2.34	No preservative.
29-34	13½	181 – 161	0.26	No preservative.
29-34	37½	126	2.46	No preservative.
24-28	24	182 – 145	1.00	No preservative.
24-28	37½	135	3.58	1.77 liters formalin added to each tank at end of 24 hours.
1	32¼	Ordinary routine	1.69	1.77 liters formalin per tank.

* Presented at the Eighteenth Annual Meeting of the Hawaiian Chemists' Association, held jointly with the Hawaiian Engineering Association, November, 1920.

"The number of tests does not warrant the expression of an opinion based on the above results. It seems that the juice stands fairly well for about 12 hours when the juice is passed through the heater at a lower temperature, but it is not safe to let the juice stand for a longer time than 24 hours, and we can safely state that the juice will not keep for 26 or more hours. There is a danger of some loss of sugar even in the case of thin syrup by letting it stand."

To these conclusions the writer would add that where the tanks were filled at a temperature below 190 and did not drop to a temperature below 160 the loss is much smaller than other cases. Mr. Iyer continues:

"Where the drippings of juice from the presses fall into the evaporator juice tank containing a considerable amount of good clarified and press juice at the end of the day, we may be certain that all that high-purity juice will deteriorate faster than when the drippings are not allowed to mix with it. Should the drippings be kept separate till next morning and then mixed up with the fresh evaporator juice and evaporated into syrup?

"The cold filter press juice from the first press, after the mill had stopped for 36 hours, was 40.6, and 39.7 purity on Monday morning as soon as the juice began to flow; if the purity is below 60, is it not better to throw that juice out altogether, as well as the cake left over in the presses? At Hamakua Mill Co., cake left in the presses over night sampled and immediately analyzed when the press cake was dumped out next morning gave an average polarization on five days of 6.4. What should be the lowest purity of the residual juice in the press cake left over night, below which the juice and the cake should be thrown out? This may not influence the final yield very much where the mill is grinding day and night, but will affect the yield in a place where only one shift prevails, especially if the dirty sour juice infects the whole boiling house and mill.

"The initial purity of the juice seems to exert an influence on the keeping quality of the juice, as seen in tests 20, 23, 24, 28, and 29-34. After 24 hours the lower purity juice deteriorated faster than a higher one. (See graph.) The following question suggests itself: What is the hourly variation in deterioration, say, up to 40 or even 48 or 72 hours? There may be some accidents in the mill which may compel the juice being kept that long without being boiled off. Under such conditions what should be the procedure or remedy to keep the juice from going back?

"Test No. 7, as well as tests Nos. 30, 32, and 34, show that when the juice is overlimed, it keeps well for a long time, but after 13½ hours it begins to drop in purity (tests Nos. 30, 32, and 34) greater than the juice showing acid reaction to litmus after 13½ hours (tests Nos. 29 and 31). This leads us to the following inquiry: Keeping the juice in the juice heater at low temperature, say around 180° F., should the juice be limed to neutrality, acidity, or alkalinity to litmus, in order to preserve for 12, 24, 36, and 48 hours, and if formalin should be added during the interval, and if so, how much? What difference will it make when the juice heater temperature is kept at 160, 170, 180, 190, and 200° F., keeping the liming and the time of the standing constant in each case? What will be the influence of keeping and not keeping the juice tanks well insulated and covered, and keeping the juice as nearly as possible at the temperature at which the tank is filled? What will be the influence of a drop in temperature of 10, 20, 30, 40, 50, and 60° F.? Also, what would be the change in procedure with juices of different purities ranging from 75 to 90 and with juices from different varieties of cane?

"Some members of the Association may have done much work along this line, and their experience and knowledge may help in throwing light on these problems."

Mr. Fries makes the following contribution:

"The 16 settling tanks at Makaweli are round, with conical bottoms, holding about 2000 gallons each, and are insulated, but not covered.

"During the past, crop tests were made at Makaweli as to the effect of temperature on the keeping qualities of the clarified juice. Mr. Walker claims two things from his experiments at Lahaina: (1) Loss of purity can be prevented by lowering the initial temperature to 180° F., and (2) formalin is of no value.

"In the tests made during May and June the juices were heated to 185° F., and the loss of purity after 20-25 hours was:

	Loss in Purity					Average.
With formalin	0.9	1.1	0.1	0.2	1.3	0.72
Without formalin	2.4	2.0	2.1	2.1	5.2	2.76

"During September—Juices heated to 185° showed after 12-15 hours:

	Loss in Purity					Average.
With formalin	0.7	0.3	0.1	0.0	0.1	0.24
Without formalin	0.5	0.2	0.1	0.2	0.2	0.24

	Time of Standing	
	15 Hours.	34 Hours.
Loss in purity with formalin	0.0	0.8
Loss in purity without formalin	0.2	2.6

"Comparisons of 212° and 185° temperature (no formalin used):

Temp.	Hrs.	Loss.	Hrs.	Loss.
212	13	0.02	19	0.45
185	13	0.22	19	0.52

These results differ radically from those at Lahaina; while the tests made in May and June indicate clearly that it pays to use formalin, even when heating to 185° F. The tests in September seemingly confirm Mr. Walker's experiments, if the time of remaining in the settling tanks does not exceed 15 hours, as for a considerably longer time of standing, the benefit of the formalin is unmistakable. It has further been brought out that the deterioration is not worse when heating to 212° than when lowering the temperature to 185°—that is, up to 19 hours.

"All this impels me to the belief that the differences between here and Lahaina and in the above tests indicate not so much a difference in apparatus or temperature, but in juices, and that by discontinuing the application of formalin, when juices have to remain in the settlers for any considerable time, the loss in sucrose involved in some factories may be a serious one, as it seems a well-established fact that at different factories the liquors are more sterile than in others. (This was found by the Experiment Station in connection with Chlorox experiments.)"

A tabulation of the deterioration of the clarified juice held over the week-end at Onomea has been contributed by Mr. White. Averages of the trials with and without formalin, and Mr. White's explanation, follow:

"The following table was compiled during the crop of 1920 and shows the inversion and losses taking place from the time the juice went into the settling tanks until it was taken to the evaporators. While no absolute record was kept of the temperature of the juice going in and coming out of the tanks, enough samples were taken to be approximately sure of the temperature. This was 89° C. (192° F.) going in and 68° C. (156° F.) coming out.

	Loss	
	Gravity Purity.	% Total Sucrose.
With formalin (15)	2.00	1.56
Without formalin (8)	2.40	1.78

"One test with formalin in which the juice stood for a longer period of time has been omitted from the averages."

Mr. Walker's contribution is as follows:

"Mr. Fries believes that the difference between his results and mine should be ascribed to a difference in the juice handled. While this may be possible, there is also the possibility that the uncovered tanks at Makaweli allow the juice to cool down below the critical point where certain bacteria can function. The open top would also tend to allow infection, even if the juice was previously sterile. Mr. Fries does not say what his final temperatures at the end of 15 or 24 hours were, and I am inclined to think most of the difference may lie there. As you remember, the experiment in which I found formalin 'worse than useless' was with an initial temperature of 212° and a final one of

196° F. On reducing initial temperatures to around 180°, deterioration in 24 hours was practically stopped, so formalin was unnecessary. It must be remembered, though, that on account of good insulation, none of my temperatures dropped below 170° in 24 hours. There certainly must be some temperature below this at which bacteria begin to get active and at which a preservative would be indicated. This point could easily be settled by keeping juice in a constant temperature oven at various temperatures. Along this line an interesting experiment would be to fill several flasks with hot juice from the settling tanks, plug with sterile cotton and let cool completely, polarizing, say, one flask every few hours to see what part heat-resisting organisms may play in juice deterioration.

"During the 1920 crop we ordinarily stopped grinding at 12 Saturday night and started up again between 6 and 8 Sunday night. Two or three 1100 cubic feet settling tanks were left full of hot juice each week from Saturday to Sunday, standing over on an average, 18 hours.

"Beginning January 17, purities were determined each week on at least one tank of juice before and after standing. Samples were taken about 2 a. m. Sunday morning and 9 Sunday night. The work was all done by our Japanese night chemist, who had no idea of its purpose, so the results could not have been influenced by any personal bias. Juice entering tanks was kept as near 180° F. as possible; on one or two occasions it went above 190°. Final temperatures were not taken, but former tests showed them to run uniformly a little above 170°.

"Following are the averages from 28 tests during 25 weeks grinding:

Average time of standing	18 hours
Average initial purity	86.37
Average final purity	86.16
Average loss	0.21

Greatest loss, January 17; juice stood 34 hours, dropped from 83.5 to 81.8. Least loss, June 26; juice stood 15 hours, rose from 79.7 to 81.6. No formalin was used this year."

The writer wished to present an extract from a report that has come into his possession on the bacterial flora of mills:

"The most difficult organism to guard against in the mill is a bacillus which for the present will be referred to as the 'High Temperature Organism.' It shows great variation in form and size, appearing as short rods, long rods, or even threads, which also vary in thickness. In this and other respects it closely resembles **Bac. Levaniformans**, and may, on further investigation, prove to be an abnormal race of that organism, which has acquired the power of growing at high temperatures, but has lost the property of forming gum. It has been found in every mill product from juice to molasses, and doubtless exists in all mills.

"It can be readily obtained by inoculating tubes of saccharose-potato-agar with any of the mill products and keeping at 130°-140° F., or by placing a flask of mixed juice in a water bath at the same temperature for from 6 to 24 hours. Though no increase of bacteria may be observed for perhaps six hours, during the following hour they may multiply two or three hundred times, so rapid is their growth when once they start. Very little change is noticeable in the appearance of the juice, so that the presence of the organism can be detected only by the aid of the microscope, though decomposition would be shown by chemical analysis.

"It grows vigorously in any mill juice lighter than 50° Brix, at any temperature between 100° and 170°, destroying cane sugar and diminishing the alkalinity; but at higher temperatures its activity ceases, though boiling, or even superheating at 260°, does not kill its spores.

"Lime in moderate quantities, up to 5% N. alkalinity, greatly assists it, while its growth is only slightly hindered by ten times this proportion (50% N. alkalinity)."

While the above report was not made on conditions in Hawaii, and so far as the writer is aware, no investigation has been made here to detect the presence of such an organism, there are strong indications that some such high temperature organism is present in our mills.

In Mr. Walker's work as reported last year the temperature of the juice did not drop below about 170° and no destruction of sugar took place. Mr. Fries does not give the final temperature in his report, but it is probable that with his

equipment the temperature fell to a point below 170°, particularly in the tests that extended over the longer period of time. It was in these tests, extending over a longer period, that the large drop in purity when no preservative was used was encountered. Some of the results found by Mr. Iyer, and Mr. White's figures, as well as a number of observations made by the writer, would be explained by the presence of such an organism.

The work that has been done on this subject in the last year or two indicates that juices held over must receive careful attention and that considerable losses, particularly in mills running in the daytime only, are liable to, and probably often do, occur through deterioration of such juice.

In the course of an investigation of the value of some antiseptic solution for the preservation of juice at this Station it was noted that mixed juice could not be preserved for twelve or eighteen hours even with formalin in the proportion of 1 to 2000. Clarified juice could be kept for several days with this strength of formalin. The difference is probably in the degree and quality of the infections. Had the clarified juice been in an active state of decomposition it is improbable that this amount of formalin would stop the deterioration entirely.

Mr. Walker has contributed the following paper on the deterioration of mixed juice to which no preservative has been added in one hour's time:

Tests on Deterioration of Raw Juice at Pioneer.

"A sample of mixed juice taken as it was leaving the mills, was cooled, kept in a covered bucket and polarized every hour. As a matter of precaution against any difference that may be due to lead, two grams of lead to 100 cc. of juice were used for each sample. These tests were made by Mr. B. B. Henderson.

Hours	0	1	2	3	4	5	6
February 19	50.5	50.3	50.3	50.2	50.0	49.9	48.8
" 24	52.1	52.0	51.9	51.8	51.5	51.3	51.1
" 26	55.0	55.0	55.0	54.9	54.5	54.1	53.8
" 27	63.6	63.6	63.5	63.3	63.1	63.0	62.8
" 28	53.3	53.3	53.2	53.0	52.9	52.8	52.8
Average	54.90	54.84	54.78	54.64	54.40	54.22	53.86
Drop		0.06	0.12	0.26	0.50	0.68	1.04
Drop in 1 hour		0.06	0.06	0.14	0.24	0.18	0.36
% of total polarization lost in 1 hour		0.11	0.11	0.25	0.44	0.33	0.66

"These tests were repeated in another series, taking the loss during the first hour only. Samples of mixed juice were taken as before, and polarized immediately and after standing one hour. No preservative was used either in this or in the preceding tests. Below are the averages of 21 tests made on separate days during the season:

Polariscope reading immediately	55.44
Polariscope reading after one hour	55.38
Average loss in reading	0.06
Average loss % total polarization	0.11%

"Four samples out of the 21 showed a slight gain, the maximum being 0.03, or within the limit of experimental error.

"Four samples, which happened to have an extra high initial polarization compared to the others, lost over 0.05 in polariscope reading in an hour, the maximum drop being from 61.54 to 61.20. Eliminating these four samples the average loss in reading of 17 samples was only 0.02, or 0.04% of the total polarization.

"These tests prove very conclusively that in the case of this particular mill at least our fears of high losses by deterioration at the mill were groundless. The loss in one hour is so slight that it requires the average of a large number of tests to prove its existence. A liberal time allowance for the passage of the average juice from the mill to the heaters would be fifteen minutes, and, since any loss due to bacterial or yeast infection increases in rate as the organisms multiply, the deterioration of our mixed juice during the first fifteen minutes can be at the most less than one-fourth of that found in the first hour or less than 0.03% of the total sucrose in the juice."

This committee was also requested to report upon "The discrepancies sometimes found between the reported composition of the final molasses before shipment and after arrival at the Coast."

On inquiry your committee found that with the exception of that shipped from one plantation, molasses that is shipped to the Coast is sampled before leaving the Islands and payment is made on the analyses of these samples. Any deterioration of the molasses while en route, therefore, does not affect the discrepancies referred to in the instructions given this committee. The differences are due either to deterioration of the samples or to differences in analyses in the different laboratories.

The following figures were furnished by Mr. J. W. Waldron, covering 18 shipments of molasses from Honokaa:

	Total Sugars.
H. S. P. A. Experiment Station	43.6
Buyers' chemist in San Francisco	41.5
Difference	2.1

In the above case the molasses is shipped in drums and is thinned to a considerable extent, so that it can be handled. Samples of this molasses have deteriorated very rapidly in this laboratory, and a part of the above differences are probably due to deterioration of the samples.

Mr. G. P. Wilcox of American Factors, Ltd., writes as follows:

"Replying to your letter of January 3rd we beg to advise that the only records that we have of the outrun of molasses shipments on arrival at destination is a report from our San Francisco office showing the total sucrose and glucose contents. It has been our experience that the analyses in this respect agree very closely with those obtained from the Experiment Station at the time of shipment. In fact, we have only one very noticeable discrepancy. These analyses were:

	At San Francisco.	H. S. P. A.
Sucrose	31.80	33.00
Glucose	18.07	19.00
Total Sugars	49.87	52.00

The following are the figures for shipment from Waianae Plantation, secured through the courtesy of Mr. Dowsett:

	1917.		1918.		1919.	
Analyses at	Sucrose.	Glucose.	Sucrose.	Glucose.	Sucrose.	Glucose.
Plantation	34.39	13.98	34.47	14.17	34.97	14.33
San Francisco	34.35	13.68	33.39	13.75	33.97	13.74
Difference	0.04	0.30	1.08	0.42	1.00	0.59
Total difference	0.34		1.50		1.59	

Mr. Swezey's Report on Attendance at the Annual Meeting of the American Association of Economic Entomologists.

Honolulu, T. H., February 25, 1921.

The Director,
Experiment Station, H. S. P. A.,
Honolulu, T. H.

Dear Sir:—I hereby report on my attendance at the annual meetings in Chicago, December 27, 1920, to January 1, 1921, of the American Association for the Advancement of Science, the American Association of Economic Entomologists, and the Entomological Society of America.

All of the numerous sections of the American Association for the Advancement of Science were held in different lecture halls of the various departments of the University of Chicago and were very largely attended. The two entomological societies met under Section F (zoological sciences) of the American Association for the Advancement of Science. There were well over one hundred entomologists in attendance at the sessions of both entomological societies, some of the more noted among them being Dr. L. O. Howard, C. L. Marlatt, A. L. Quaintance, A. F. Burgess of the U. S. Bureau of Entomology; E. D. Ball, Assistant Secretary of Agriculture; J. M. Aldrich of the U. S. National Museum; C. T. Brues and W. M. Wheeler of the Bussey Institution; V. L. Kellogg of the National Research Council; E. P. Felt of the New York State Museum; Arthur Gibson, Ottawa, Canada; P. J. Parrott, State Entomologist of New York; W. C. O'Kane, State Entomologist of New Hampshire; Professor Herbert Osborn of Ohio State University; H. A. Gossard, State Entomologist of Ohio; J. G. Sanders of Pennsylvania; J. J. Davis of Indiana; Wilmon Newell, Florida; S. A. Forbes and J. W. Folsom of the University of Illinois; A. L. Melander, Washington; W. E. Hinds, Alabama; Glenn W. Herrick and W. A. Riley, Cornell University.

The Entomological Society of America, of which Dr. L. O. Howard was president and Dr. J. M. Aldrich secretary, had sessions both forenoon and afternoon for two days. Eighteen papers were presented, usually being followed by discussions. Some papers had to do with life histories, others with structure, and some with parasite relations, while others dealt with geographic distribution. In most instances they dealt with insects of more or less economic importance in some part of the United States.

One paper dealt with Bacterial Symbionts of Blattidae. From the author's illustrations exhibited, the organisms treated of as occurring in roaches, and which he called Bacteroids, are similar to the yeast-like organisms which have recently been found to be abundant and always present in our sugar cane leafhopper, as well as in all of the native leafhoppers of the Delphacidae which have been examined. This is a line of interesting investigation, as little is

known yet of the role these organisms play in their host insects,—whether detrimental or not. A few other kinds of insects have been found to contain them.

Professor Osborn had a paper on some leafhoppers of forest trees, and Z. P. Metcalf gave a review of the Fulgorid leafhoppers of North Carolina, of which 270 species are now known.

Dr. Howard gave a lantern-slide exhibition illustrating his last summer's visit to Europe. He showed pictures of the many entomologists visited and gave many interesting incidents of his trip, which was mainly to England, Belgium, France, and Italy.

The American Association of Economic Entomologists, of which Wilmon Newell was president and A. F. Burgess secretary, had both forenoon and afternoon sessions for three days, following the meetings of the Entomological Society of America and attended by mostly the same entomologists. Thirty-five addresses and papers were presented, many of them illustrated by lantern slides. One of the sessions was held jointly with the American Phytopathological Society, the purpose of the joint session being a symposium on "Dusting as a Means of Controlling Injurious Insects and Plant Diseases." This brought out that dusting is the more profitable method to use when conditions and circumstances permit its use. More area can be covered in the time and the machinery used is not so expensive as where spraying is employed. Dusting has been used successfully against the cotton boll weevil in the south, also against curculio and codling moth in Michigan. In the latter instance, apple scab was not so well controlled by the dusting method.

I can not attempt to review all of the papers presented, but will make some mention of some of the prominent ones of the regular sessions.

The European corn borer came in for a considerable part on the program. It is a moth whose larva bores into corn stalks and a number of other plants. It is now considered that it was introduced to eastern United States by importations of broom corn from Europe. It has been known in eastern Massachusetts but a few years and has already spread into New York state, where the infested area now covers 22,000 square miles, and the spread is about twenty-five miles per year. Some isolated places in western New York and northwestern Pennsylvania are considered to have occurred from recent importations of infested broom corn. Recent observations show that it is not to be considered such a serious pest, although large appropriations are asked for to combat it and check its spread. It is found that corn in low places is most subject to infestation and that there the common extent of infestation was twenty-five per cent of the stalks, while a thirty per cent infestation was necessary to cause commercial loss; and a ninety per cent infestation even is not a total loss of crop. Control work has developed a crushing machine for putting through corn stalks, stubble, etc., to destroy larvae and pupae therein. One machine can handle twelve to fifteen tons per day. An oil-spraying burning machine has been devised, also, capable of burning a strip twelve feet wide, and to treat twelve to fifteen acres per day. Work has also begun in introduction of parasites for the corn stalk borer.

Corn aphis was reported as a bad pest on corn in Kansas, where it is found

necessary to plant early, May first, to avoid injury. This aphis is the same as infests corn here, though not so seriously as the corn leafhopper. It is likely that here some special planting season could be found that would be most favorable to avoid injury by this pest.

Several papers dealt with a leafhopper occurring on potatoes, in connection with a condition of the leaves called "tipburn." Experiments have proved that the tipburn is caused by this leafhopper and that it could be controlled by spraying with Bordeaux, which acted as a repellant rather than an insecticide. Nicotine sulphate and kerosene emulsion were found ineffective against this leafhopper.

In a report of control work with the pecan case bearer in Texas, is an example of great loss produced suddenly by an insect probably always present. This is a tiny moth larva which is found on pecan trees. In 1920 they attacked the nuts, when very small, to such an extent that there was almost a complete failure of the crop, whereas the crop in Texas for the previous year was 1000 cars. Experiments showed that spraying with arsenate of lead gave ninety per cent protection.

Among apple insects, the codling moth received attention in the way of discussion of recent experiments in its control. It is a pest that the apple grower always has to reckon with. Marketable apples can not be grown without spraying at the proper time, and often two or three times are necessary, determined by conditions prevailing in the locality, and differing for the different apple-growing sections of the country. For instance, the entomologist from Washington stated that there one spraying when the calyx was still open, together with a later thinning of any wormy young growing fruit, was sufficient to produce nearly one hundred per cent sound fruit.

The green Japanese beetle situation in New Jersey continues to increase in seriousness. Mr. C. H. Hadley, at present in charge of control work, gave an account of the present status of the work. The beetle is continuing its spread in spite of very extensive measures employed to prevent it. A zone surrounding the infested area is kept dusted or sprayed to endeavor to hold the beetle within bounds. This pest as compared with our *Anomala* differs in its method of attack. The adult beetles do the damage to crops by feeding on the foliage like our own Japanese beetle (*Adoretus*). The grubs in the ground do not injure crops by eating the roots as our *Anomala* did in the cane fields. Their grubs are more trash feeders and do not injure crops. They occur very abundantly under litter and roadside trash. Immense quantities of the beetles and also the grubs are being collected and all known methods of using insecticides against them are being employed, but still the infested area increases annually at a rapid rate. This region in New Jersey is near the Delaware River a little above Philadelphia. In 1920, in spite of attempts to prevent it, the beetles crossed the river over into Pennsylvania and became established to some extent. On this account an area there of about seventeen square miles is quarantined. An attempt is being made to find in Japan parasites which may be introduced to help check this pest, two men being employed in that work at present. They are encouraged in this by our experience in Hawaii in introducing *Scolia* as a parasite on *Anomala* grubs, which it has so effectively checked.

In connection with the cotton boll weevil, some data relative to the value of birds is of interest. In Texas, quail are abundant and search the cotton fields for insects, which are their normal diet. Examination of quail crops and stomachs has shown ninety-two per cent of them to contain cotton boll weevils, and as high as forty-seven of these beetles per quail. And yet in a state where there is an annual loss of $150,000,000 due to the boll weevil they fail sufficiently to protect the quail which destroys such great quantities of the weevils. The present protection laws allow a hunter to bag up to thirty-five quails per day. The value of the quail as a source of sport or food is small compared to its value as an insect destroyer. Many other birds (even game birds) could be placed in the same category.

A lantern slide exhibition was given by myself of the important sugar cane insect pests in Hawaii and their introduced parasites, together with some account of these. I also presented a paper on "Recent Insect Immigrants in Hawaii," in which I listed and gave notes on twenty-eight foreign insects which were observed for the first time during 1919 and 1920. Most of these are of no economic importance; some are beneficial, being parasites; only a very few are injurious or likely to become pests or to require any control measures being employed.

Along this line, Mr. E. R. Sasscer gave a paper on "Important Foreign Insect Pests Collected on Nursery Stock in 1920." They are always finding new pests on imported plants, which shows the importance of establishing more effective quarantine measures. One whole afternoon was taken up with papers and discussions relative to the present methods of quarantine, the special insects quarantined against, and plans for further extension of such quarantines.

Of interest in this connection was an account of the recently discovered area in New Jersey infested by the gypsy moth. This is on the Duke's Farm Company at Sommerville, where blue spruce trees from Holland were imported and planted several years ago. Later (1913) some of the trees were removed and shipped to various parts of the state, some even outside the state. Recently the blue spruce grove was found to be infested with gypsy moth, and tracing the shipments of trees made from there in 1913, eight other places, within an area of ninety square miles were found infested by gypsy moth apparently from this source. It is now considered that all this has resulted from there being one or more gypsy moth egg masses in the original lot of imported blue spruce trees planted by the Duke's Farm Company. At great expense attempts are being made to eradicate the pest in these places.

Strenuous efforts are being made by the Federal Horticultural Board to keep the pink boll worm from gaining a permanent foothold in Texas, by quarantine work at the points of entry on the border line between Mexico and Texas. Cotton and cotton seed are prohibited, of course, and they have immense fumigating sheds capable of fumigating fifteen freight cars at once, to fumigate all freight cars coming across from Mexico. These are at Brownsville, Laredo, and El Paso. Fourteen thousand freight cars are fumigated annually. Passengers are also inspected, as a good many Mexicans go up to Arizona to pick cotton and for other labor, and have been found carrying cotton pillows, etc., amongst their

luggage. Avocadoes are prohibited at these places also, and they find the Mexicans smuggling them across in many ways. They have been found concealed in loaves of bread, and hidden in or beneath women's clothes.

One evening session was held, devoted to the Apiary Section, at which was a symposium on "Foulbrood," and other papers on problems of the industry. A new phase of the bee-keeping industry is practised by a bee-keeper in the suburbs of Chicago. He supplies hives of bees to the gardeners who grow cucumbers under glass, for the purpose of having the cucumber flowers pollenized by the bees. One to ten hives are supplied, according to size of greenhouse in use.

On one evening an Entomologists' dinner was held at the Hotel Sherman. More than one hundred entomologists participated. Representatives of various entomological societies were called on for brief remarks. I represented our local entomological society and was the most distant member in attendance.

On one other evening occurred the Annual Osborn Dinner, at which twenty-five of us, who had at some time studied entomology under Professor Herbert Osborn, sat at table with him. It is worthy of note that so many of the entomologists in attendance at the meetings, and holding important positions all over the country, should at some time have had work with Professor Osborn of Ohio State University. After dinner each one present was called on to give some account of himself, with special reference to recent activities in entomological work, and a very interesting hour was spent.

On my return trip I visited entomologists at the Sugar Station at Audubon Park, New Orleans; at Phoenix, Arizona, and at the Citrus Experiment Station, Riverside, California. Mr. E. R. Barber at Audubon Park told me of his work in the introduction from Cuba of a Tachinid parasite for the sugar cane moth borer in Louisiana. A small number of puparia had been obtained in 1919 and from them the parasite had become established in the cane field at the Station. In 1920 a number of the cane growers contributed to a fund for further introductions of the parasite. Mr. Barber with four assistants went to Cuba for a few months in the summer and collected over seven thousand puparia of the parasite. There was a very good percentage of emergence from these at the Station, and the parasites were distributed to all of the planters who had contributed to the fund. The chances of the parasite becoming permanently established were considerably lessened thereby. But each planter was insistent that he should receive something for his money contributed, which necessitated their division into such small colonies that they may prove to have been inadequate. It yet remains to be seen whether the project was successful.

At Phoenix, Arizona, is a large area of land irrigated from the Roosevelt Dam. In 1920 it was mostly in cotton, a large crop being obtained. A longer staple variety is grown and a better yield per acre is obtained than in the Gulf States. The State Entomologist told me of their efforts to protect the cotton regions in Arizona from a weevil, which is related to the cotton boll weevil, which has been discovered attacking a native cotton growing in the mountains of Arizona. Scouting is carried on to eradicate this native cotton where it grows along stream beds from seeds carried down from the mountains by these mountain streams. So far the weevil has not appeared in the cultivated cotton fields.

The Citrus Experiment Station at Riverside, California, is a part of the University of California. Mr. Quayle, the entomologist in charge, has been working of late on control of codling moth on the walnut, a new food habit for this pest. Mr. Stahl, of the U. S. Bureau of Entomology, is stationed here and is carrying on investigations with the sugar beet leafhopper. It is a much smaller insect than our sugar cane leafhopper and does not occur in such great numbers as our leafhopper has at times, but it takes only a few to cause great injury to a beet field, for they transmit a disease called "curly leaf," which very much cripples the growth of the beets. This disease occurs on certain native weeds on which the leafhoppers feed for a part of the year, and is transmitted to the beets when fed on by leafhoppers which have fed on the diseased weeds. This leafhopper has several parasites which would perhaps keep it sufficiently controlled if their actual feeding on beet leaves was the only thing concerned. But in their transmitting the disease such a small number are necessary to accomplish this that it will require almost complete extermination of the leafhopper to accomplish much benefit, or the eradication of the weeds that are also affected by "curly leaf" disease. This is perhaps less possible than the former. They have a very complicated problem. One line being followed is in the production of immune varieties of beets.

On the trip I also visited several large museums to see what is being done in entomology: Field Museum at Grant Park, Chicago; Matthew Laflin Mills Museum at Lincoln Park, Chicago; Museum of the California Academy of Sciences, Ocean View Park, San Francisco, California; Southwest Museum at Los Angeles, California; also the Entomological Laboratories of the University of California, Berkeley, California.

Respectfully submitted,

O. H. SWEZEY,
Entomologist.

The Use of Sugar Cane Molasses as a Fertilizer.*

M. de Sornay, the Director of the Agricultural Research Laboratory of the "Colonial Engrais Chimiques" at Port Louis (Mauritius), draws attention to the importance of sugar cane molasses as a fertilizer. The market value of this substance is very small, and the results obtained with it in Mauritius and numerous cane-growing districts leave no doubt as to its efficacy as a fertilizer. It is used after having been thrown on the dung-heap for the purpose of hastening its decomposition, or mixed with sugar-refining residue and ashes, that is to say, in the form of an actual compost known as "saccharogene," which is thrown in a

* From The International Review of the Science and Practice of Agriculture.

concentrated condition into the trench before planting, or placed at the base, or spread between the rows.

According to the experiments mentioned by M. de Sornay, the increase in yield thus obtained varies from 5 to 10 per cent.

M. de Sornay has investigated the reasons for the increase in yield, small though it is, obtained from sugar canes that have been manured with molasses. He carried out most careful experiments with a view to determining whether the presence of sugar was favorable to microbial action in the subsoil, and to the fixation of nitrogen, and how far, under the influence of the disappearing sugar, the elements of the soil became disintegrated and transformed into more soluble substances. The results which he obtained were, however, not sufficiently conclusive to permit of his attributing the efficacy of cane molasses to any of these causes. In short, its utility does not seem to depend upon its potash content. Although M. de Sornay has thus been unable to solve in a satisfactory manner the problem he set himself, he does not deny the efficacy of molasses as a fertilizer.

[R. S. T.]

Forty Years of Boiler Explosions.*

The Locomotive, the house organ of the Hartford Steam Boiler Inspection and Insurance Co., contains in its October issue a summary of that company's statistics on boiler explosions that have taken place in the last forty years. The total number of explosions covered is 14,281, in which 10,638 lives were lost and 17,085 persons injured. These figures are not, of course, complete, especially in regard to the number of boilers in use, for no means are available of securing complete records of boilers throughout the country. They may, however, be taken as fairly representative and indicative in a general way of conclusions that would be drawn from a more comprehensive survey.

The figures comprising this summary have been put into graphic form, as in this way their significance is more readily grasped. It should be remembered, however, that charts of this nature must be taken in a very general way. That is, the "saw-teeth," or sharp, extreme changes, are not in themselves of much importance. The general trend of the lines, however, shows more clearly than figures possibly can, just what the situation is.

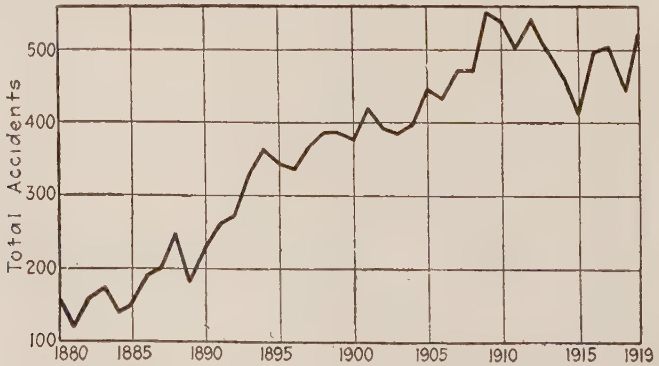


Fig. 1. Total explosions per year.

* Power, November 16, 1920, p. 786.

Fig. 1 shows the rise in the number of explosions per year since 1880. This chart must be considered in the light of the obvious fact that the number of boilers in use has increased steadily; but whether that increase has been less than, equal to, or greater than the increase in the number of accidents cannot well be determined. However, it will be noticed that from 1909 on, a slight and widely varying, yet decisive drop, is apparent; and it scarcely seems possible that the number of boilers in use since 1909 could have decreased or even remained constant. That it has, on the other hand, increased, is a reasonable assumption. This, of course, leads directly to the conclusion that the ratio of the number of accidents to the number of boilers in use has decreased since 1909.

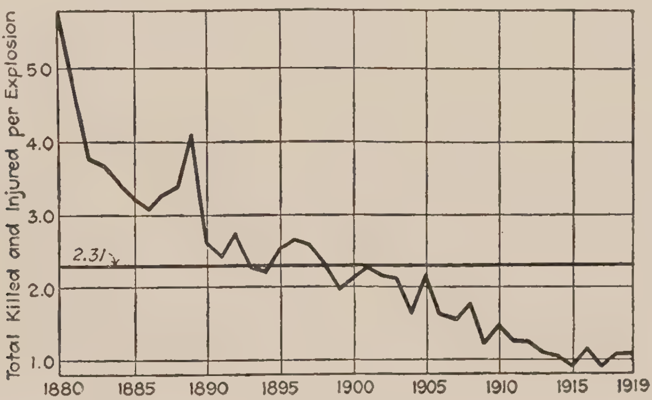


Fig. 2. Total killed and injured per explosion.

Fig. 2 shows a very marked decline in the number of persons killed and injured per explosion. The line marked 2.31 represents the average of the totals for each year. It can be seen that whereas in 1880 more than five persons were killed or injured in each accident, this figure came down to about one in 1919. This curve is of especial interest because of its very pronounced downward trend and because of possible speculation as to its cause.

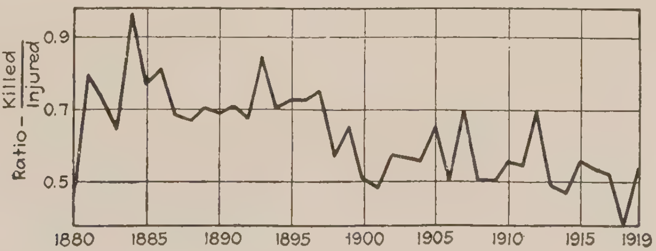


Fig. 3. Ratio between killed and injured.

Fig. 3 represents the changes in the ratio between those killed and those injured in each explosion. While this curve does not fall so rapidly as that in Fig. 2, still it does drop appreciably. It shows that at first there were almost as many killed as injured, and that now the killed are about half of those injured.

Taken as a whole, these facts are rather gratifying than otherwise. Though they are incomplete, they indicate with a fair degree of certainty a trend in the

right direction. The apparent decrease in explosions relative to the number of boilers in use, the reduction of casualties per explosion, and the smaller proportion of fatalities point to increasing care in the construction and operation of boilers.

[W. E. S.]

Installation of Battelle's Plantation White Sugar Process in the Central Jovero, Dominican Republic.*

A large factory to be known as the Central Jovero is being erected at Samana Bay, Dominican Republic, by the Honolulu Iron Works for the American Dominican Sugar Co., of New York, the capacity of this plant being 1500-2000 tons per day. It is of interest to note that the Battelle process for the manufacture of a plantation white sugar (quite equal in quality to the "standard granulated" of the American beet factories) will be employed. This process, it will be remembered,[1] consists briefly in boiling the cane juice with an excess of lime (the "glucose" thus being destroyed), and applying the carbonatation process, after which the light-colored juice obtained is concentrated and boiled to grain in the usual way. A feature of this method of working is that the sugar ordinarily lost in the molasses is recovered by means of the Steffen process, an increased recovery of about 5 per cent being thus obtained.

Mr. E. Erle Battelle (who will be in charge of the El Jovero plant) is reported as having stated that: "It is understood the cane contractor will delive not less than 200,000 short tons of cane per year to our mill by ox carts or loaded into our railroad cars at sidings. The yield of sugar will not be less than 12 per cent or 24,000 tons per year of granulated sugar, of which 12,000 tons (50 per cent) will be delivered to the cane contractor as his portion of the product and as full payment of his delivered cane, and the remainder of 12,000 tons granulated sugar to be our share of the product. The estimated costs and charges, including labor, packages, supplies, railroad operation and repairs, repairs equipment, administration costs, and fixed charges and depreciation should be 1.5911 cents per pound sugar produced and 3.1822 cents gross per pound cost to us. This outside cost for our granulated sugar, before dividends, of 3.1822 cents f.a.s. will permit us to deliver, duty free, at Atlantic ports of the United States at the additional cost of 0.4579 cents for insurance and freight and 1.36 for full U. S. duty, or a total cost on the American market of 5 cents per pound."

[R. S. T.]

* New York Record, October 8, 1920, reprinted in International Sugar Journal, 22:708, 1920.

[1] See I.S.J., 1912, 163; 1913, 47, 535; 1914, 181, 484; 1915, 357; 1919, 577.

The Mosaic or Mottling Disease of the Sugar Cane.*

THE MAIN FACTS OF THE CASE TO DATE.

By C. A. Barber.

Mosaic of the sugar cane is perhaps the disease of the hour. This is not necessarily because it is the most widely distributed or the most important, but rather because two parts of the United States, noted for the excellence and profusion of their publications on agricultural matters, are undergoing a somewhat acute phase of anxiety on account of it. In Porto Rico it has been noted sufficiently long for a fairly detailed estimate to be made of the losses attributable to it; although it may well be doubted, in view of the facts presented in the paper on Root Disease in that island in the last number of this journal, whether at some future and calmer moment, the figures given may not be regarded as the reverse of conservative, as they are now claimed to be. And, in the United States, the officers of the Agricultural Department, alarmed by these figures, have with characteristic energy investigated the matter, and, within a year of the discovery of the disease there, produced a mass of evidence that it has caused serious losses during recent years, and published broadcast the means by which it can be kept under control.

Our attention was first directed to this disease, possibly long familiar to us in the cane fields of the tropics, by a lively controversy in our contemporary, the Louisiana Planter, in which the scientific workers in Porto Rico and Louisiana and to a less extent in Hawaii on the one side, and those in Cuba and Argentina on the other, became involved. While it is said to be a serious disease in Hawaii, it has been known there since 1910 and is under control; in Porto Rico it was first detected in 1915, and is rapidly enveloping the whole of the island and causing much loss; in the continental United States it was definitely named in 1919, and was then found to have spread to all of the sugar-growing States in the south; in Cuba it had been noted by responsible officers 18 years ago, and is of local distribution and minor importance; while in Argentina it has been present for at least 15 years, and is now so universal that it is almost impossible to find a single plant free from it; here, again, it is not regarded as serious.

With these various and conflicting opinions before us, we watched the contest and "sat on the fence," having no means of judging the validity of the arguments on either side. But a series of exhaustive papers have recently been published by American workers in Porto Rico and the United States, and we have been able to form more definite conclusions as to the real state of affairs. We propose in this article to lay these conclusions before our readers, without in any way claiming to be arbiters in such matters as are still in dispute. We merely intend to try and summarize the more important aspects of the question, as detailed by the responsible officers on the spot, whose attainments are unquestioned and whose opinions are worthy of the most careful consideration.

* The International Sugar Journal, 23:12-19, 1921.

It may be well, in the first instance, to give a short résumé of the controversy as presented by the articles in the Louisiana Planter during the past year, the figures in brackets giving the date and page of each of these.

(1) J. R. Johnston, a recognized authority on cane diseases in the New World and until recently Pathologist at the Central Experiment Station in Cuba, opened the ball (July, 1919, p. 43) with a reference to recent articles in the Havana papers which indicated that the Mosaic disease was present in that island. He detailed the main character of the disease in Porto Rico as follows: Its cause was unknown, but it was not a simple chlorosis; it was injurious and transmitted by cuttings; the soil was incapable of transmitting it, and it was incurable; its attacks differed in different varieties, from immunity to heavy infestation, from serious damage to considerable resistance; it might remain harmless for a series of years and then suddenly leap into prominence and spread rapidly. The disease appeared to be identical in Porto Rico and Cuba, as well as in Hawaii and Java, where it had been known as Yellow Stripe for some time; it was therefore advisable to watch it carefully in Cuba.

(2) This paper of Johnston's provoked a reply from R. M. Grey, Superintendent of the Harvard Experimental Station, Cienfugos, Cuba (August, 1919, p. 90), contesting Johnston's facts. Grey stated that he had found the disease 18 years before and had kept it under observation for 14 years. He had carefully examined it and, as the result of innumerable observations and experiments, considered that it did no damage; he further stated that it was not incurable, and claimed that he had repeatedly succeeded in eliminating it by improved cultural methods; he had never found a case where it was fixed and permanent; "mottling disease causes absolutely no injury in Cuba, and if root disease and leaf rot could be eliminated we might forget it."

(3) The Editor of the Louisiana Planter (August, 1919, p. 82) drew attention to Grey's paper, and quoted the case of frog-hopper in Trinidad, where far less injury was caused where the earth had been properly worked: and he also drew attention to the various alarmist predictions regarding borers which had not materialized and the divergent views held by scientific officers as to the usefulness, in fighting them, of burning the trash.

(4) As was natural, this brought Porto Rico into the field. F. S. Earle, Expert in Sugar Cane Diseases, of the United States Office of Sugar Plant Investigation, and now working in Cuba (September, 1919, p. 167), regretted the tone of recent articles in the Louisiana Planter. Considering that the behavior of the disease was contradictory, remaining harmless for years and then suddenly springing into activity and causing widespread loss, it was the best policy to attack it while it was in the quiescent stage. Considering Grey's claim to have eradicated it by cultural methods, he suggested that that worker might have confused true mottling with the often similar attacks of insects and fungi. The disease was now widely spread throughout continental United States, and it would be unfortunate if planters there were lulled into a false sense of security. The Editor added a note to this letter maintaining the view previously expressed by him and referring to the campaigns against the cotton boll weevil and yellow

fever, where success had, after enormous sums of money had been expended, been obtained through comparatively simple side issues.

(5) Grey, declining to enter into a discussion on the subject, simply stated (September, 1919, p. 199) that he had made no such mistake, and had cured the actual plants, identified by the United States experts as suffering from the Mosaic disease, in 116 days, and others equally badly affected in 59 days. He suggested that, from what he had read, the weather and other natural conditions in Porto Rico seemed to be more severe than in Cuba.

(6) Lastly, G. L. Fawcett, Botanist to the Agricultural Department in Argentina, a consistent student of sugar cane matters, wrote (January, 1920, p. 39) an article discussing the effects of Mosaic in that country, as probably of interest. He had noted the spotting of the leaves on reaching Argentina four years before, but, in the absence of apparent damage, had turned his attention to the really serious sugar cane diseases. Recently, this spotting had been identified by Porto Rican and Hawaiian experts as Mosaic. The disease was known 15 years ago in Jujuy province, and it was now practically impossible to find a single plant in Argentina not infected, except in a small area in the south of Salta, and that the infection was doing no apparent damage. The thick canes of the country had, it is true, been driven out, but he did not regard Mosaic as the cause. This was rather due to the difficulty of such varieties in rapidly establishing themselves after harvest before the cold weather set in, thus suffering from decay of the roots and stubble before the spring. Various Java seedlings, while freely infested with Mosaic, were better able to stand the adverse climatic conditions and the Mosaic did them no harm, as evidenced by the tonnage obtained. Fawcett, however, disagreed with Grey in Cuba in one particular, in that he found better cultivation of no avail against Mosaic, nor had he ever seen a plant recovering from it when once attacked.

This controversy has been of great value, and justifies the conclusion that the disease is in some way dependent on local conditions, so that its behavior is contradictory in different countries, as is so often the case with cane diseases. Like other diseases, it is capable of long periods of quiescence and harmlessness, but in certain circumtances may suddenly increase rapidly and become a serious infectious disease. And, such being the case, it is the only wise course to search for it everywhere, and when found to keep it under observation, meanwhile taking note of the methods which from time to time and place to place have been found to keep it in check. Thus, if it becomes dangerous, it can be at once treated with full knowledge so as to limit its harmful character. It might be mentioned, lastly, that the discrepancies brought out in this interchange of views in the Louisiana Planter should be cleared up, especially the claims that Mosaic can be influenced by better cultivation in Cuba.

In the following notes on Mosaic a number of papers have been consulted, the most important of which are mentioned below: these are such as have come our way. It is claimed in Hawaii and elsewhere that Mosaic or Mottling is identical with the Java Gele Strepenziekte (Yellow Stripe), first mentioned by Musschenbroek in 1892 and subsequently studied by a number of other workers in Java. Lyon of Hawaii gives the following distribution of Yellow Stripe:—

Hawaii, Fiji, Australia, New Guinea, Java, Philippines, Egypt, to which may be added Porto Rico, San Domingo, Cuba, Argentina, St. Croix, and lastly (I.S.J., 1920, pp. 669 and 670) Trinidad and Jamaica. It has in these places accumulated a multitude of names, of which Mottling or Mosaic seem to be the best. The latter name seems most likely to survive, because it is the name current in the United States and at present in Porto Rico, is descriptive of the disease and especially, indicates its relationship to the mosaics of tobacco and other plants.

The following are some of the main characters: a full description is impossible within the space available and will not be attempted. The chief character is of course a mottling or striping of the leaves caused by the occurrence of dots and short stripes of lighter green and, somewhat later, white, scattered over the darker green background of the normal leaf: these increase in number, coalescing in various ways so that the normal green color becomes the exception and the whole leaf takes on a pale, often yellowish tint. A great variety of patterns is thus produced on the leaf, and these are distinguishable from those caused by fungi in that the invaded tissue does not die and turn brown, and from the spotting by sucking insects in that these are almost invariably surrounded by a pale almost circular area: the larger spots in Mosaic are invariably elongated. It is distinguished from the various forms of non-infectious chlorosis by the distribution of the light coloring which, in the latter, is usually local: in Mosaic the whole leaf is infected excepting sometimes at commencement. This affection of the main feeding organs of the plant, whereby the color bodies are killed, is naturally accompanied in most cases by feebler growth, and the plants become stunted. The new internodes are shorter and thinner, and, at a later stage, show lesions or cankers on the surface, become less juicy and even pithy, until finally no commercial canes are produced and the field has to be abandoned. This last stage usually occurs in the third year from planting, but this will depend upon the relative power of resistance of the variety. The plants do not appear, however, to be killed by Mosaic: they merely become unprofitable from the crop point of view.

The disease is passed from generation to generation and field to field primarily by the sets, and as, once attacked, the whole of the tissues are affected, no part of a diseased plant can produce healthy offspring. But the disease is also highly infectious: a secondary form of transmission is quite obvious, for diseased plants rapidly contaminate all that are near to them and also, in many cases, appear to be able to do so over very considerable distances. It has been definitely proved that this secondary infection does not take place through the soil, and, once an abandoned field is plowed up and none of the old shoots allowed to develop, perfectly healthy canes can be grown if taken from plants in their turn healthy. This negative action of the soil has been proved in various ways again and again, one experiment being to place healthy sets in pots from which diseased plants have just been removed. The mechanics of secondary infection has not to all appearance been definitely worked out as yet, but there is the strongest evidence that insects of the sucking kind, often powerful fliers, are concerned in this natural inoculation. Their action appears to be most effective, and yet all attempts to carry out artificial inoculation appear to have failed or, if they have

succeeded, only so in the rarest cases. Insect carriers further explain the observed facts, and aphides and frog-hoppers are suspected, acting presumably just as they do in the allied curly-top disease of the beet and some other diseases. In these cases a very small amount of virus is sufficient to infect a great many plants, and this may well be the case with cane Mosaic, as the spread of the disease by secondary infection is remarkable for its rapidity. The period of incubation appears to be from two to three weeks and the disease appears within six weeks or two months of planting.

No organism of any kind has been found in the tissues to which the disease can be attributed, and the view generally expressed is that we have here to do with an ultra-microscopic organism or perhaps a perverted enzyme,—which is, after all, rather a confession of failure, just as in the old days when an obvious fungus was not found in the tissues of a diseased plant it was often suggested that bacteria were at work. But the behavior is so like that in cases of demonstrable infection by fungi or bacteria, and the number of similar unexplained epidemics is so great, that there is much to be said for the theory. This is one of the many riddles which phytopathologists have to solve. There are quite a number of diseases, frequently rapidly spreading and very deadly, for which no adequate cause has been found. We need only mention the sereh disease of the sugar cane, the spike disease of sandal, peach yellows and curly-top in the beet. At first it was frequently held that the disease was induced or at any rate largely assisted by deterioration, another refuge for the destitute, or by bad weather, soils, manuring, cultivation, and this last has received some encouragement from the statements of Grey in Cuba. But, for the disease in its destructive form, the very complete study to which it has been subjected has knocked away these props one by one, till it is generally conceded that to no single one or combination of them can the disease by any chance be attributed, and there is nothing left to fall back upon but hypothesis.

The behavior in different countries varies a great deal and this is yet another of the riddles with which the study is beset. At the same time, such differences should be of the greatest interest and open out a wide field for investigation, and appear to afford a series of clues which will doubtless be taken advantage of by the workers in those places where the disease is most feared. In Java it has been recognized as causing appreciable loss, but is apparently controlled by the continued planting of sound seed; it is suggested that the disease was, in any case, less virulent than in the New World in these latter days, and this has been attributed by some to a quantum of resistance acquired naturally by the cane plants long growing with the disease in their midst. Similar suggestions have been made by others regarding San Domingo and Cuba to be mentioned below. The Hawaii work, though doubtless very interesting, is not available; but it is indicated that, in fully infected fields (100 per cent), the loss is from 5 per cent to 40 per cent, according to the variety grown, and that this loss is in the form of deficient tonnage rather than diminished growth of poorer juice. In the early stages mottled plants grow well and their juices appear to be equally rich in sugar with healthy ones, but the stalks are always considerably lighter and presumably have less juice in them. In Porto Rico, four years' severe infection has made it

possible to advance more detailed figures than in continental United States. Stevenson estimates that, up to July, 1919, some $3,500,000 had been lost to the industry through mottling, and it is quite certain that the damage since then has been very serious. No statement can very well be made in Louisiana, for the disease was only definitely declared to be present in the same month (July, 1919), but, from such evidence as has been collected during the very detailed survey which has been concluded, it is thought probable that considerable losses have been experienced during the last few years. In San Domingo the disease is reported by Stevenson as widely spread, but not assuming the severe form of the Porto Rico epidemic; no case of stem infection has been met with by that observer and he hazards the suggestion that the virgin soils of the cane plantations may have something to do with this. This has also been urged with reference to Cuba, and certainly the disease acts there in a totally different manner from Porto Rico and the United States generally. There seems, in fact, to be little or no secondary infection and the disease has difficulty enough to hold its own with the reproduction by diseased sets. It is, as will be gathered from the former remarks by Grey, regarded with equanimity. In Argentina, on the other hand, yet another case is presented. Here too the disease is not regarded as dangerous, but this is traced to the fact that the canes growing, although fully infected, are almost entirely of varieties which, everywhere and even in Porto Rico, have shown a very high state of resistance to Mosaic, the older varieties having been discarded in this sub-tropical region in favor of Java seedlings with North Indian blood in them.

A natural means of fighting the disease is of course the introduction of immune varieties, the final refuge of all who have failed in their attacks on plant diseases. But, unfortunately, the only varieties which have hitherto been shown to be immune are such as cannot be commended for growing in tropical cane fields. Such are the Kavangire, determined by Cross to be identical with Uba, Cayana 10 used for syrup in the United States, and other so-called "Japanese" canes wherever found; typically thin, fibrous, freely tillering canes, possibly all of the great Pansahi group of Indian canes. Besides these there is the possibility of some new seedlings being found which are immune, but at present more than 1000 kinds have been shown to be susceptible, including all the well-known canes of commercial value and multitudes of seedlings; and, considering the parentage of the latter, it seems at least improbable that they will be found to differ from their parents in this matter of immunity. But we must here distinguish between immunity and resistance, two very different things. The Java seedlings referred to above are not in the least immune and take the disease with the greatest ease, and it is possible that they have introduced Mosaic into the new world; but its effect on them, although varying, is very slight, and perfectly good yields can be obtained from 100 per cent infected fields. The suggestion that this resistance is due to long experience of the disease in Java has already been referred to; but it seems to us to be much more likely that they owe this favorable character to their parentage, which is half North Indian, although in a different group to that of Kavangire. The Saretha group, to which their male parent belongs, is a much hardier one in India than the Pansahi. There is hope,

however, in this matter of resistance, for the thick canes vary greatly in it: quite a number are mentioned in the various papers referred to as more resistant than the rest, and trials have commenced with these both in Porto Rico and the United States. Thus, G.C. 888 and G.C. 1313, D 1135, D 117, B 6540 and L 511 are said to be worth multiplying for this reason, and L 1646, L 1606, L 1674 and L 1797 even show signs of possibly being immune.

One of the most interesting features in the case, which has only recently received attention, is that the particular virus attached to Mosaic in the sugar cane is capable of producing a similar disease in various other members of the grass family. This point has as yet by no manner of means been fully worked out, but Mosaic occurs, according to Brandes, in maize, rice, "millet," sorghum, "Panicum," foxtail, and crab-grass. The disease is said to attack these plants with difficulty even under favorable conditions; but, while it is likely that all of these plants can be infected directly from sugar cane, this has only been proved in the case of the last four. These became heavily infected when grown in the same greenhouse as diseased sugar canes while plants growing all around outside remained without a sign of Mosaic. The importance of this aspect of the matter cannot be overrated. It is sometimes assumed that the disease was originally one of some wild grass which handed it over to the sugar cane, and this idea receives some support from the peculiar mode of extension in Porto Rico, where it was at first chiefly met with in the hilly tracts. However this may be, the possibility of the wild grasses bordering cane fields acting as carriers is alarming enough for a detailed search to be made on plantations for any signs of the disease in the wild flora as well as in adjoining crops.

The control of Mosaic disease, as in sereh and many other diseases, outstripped our scientific knowledge of its character, and is planned upon a recognition of a couple of clear-cut factors. Diseased plants will always transmit the disease through cuttings taken from them, and secondary infection always takes place when susceptible varieties are planted near those affected. When the characters of the disease are universally known to planters and they can readily distinguish Mosaic plants from those with leaves otherwise marked, it should be easy rigidly to abstain from taking sets from diseased plants. In one case we can go further, for Egerton has shown that, in L 511, we can at once distinguish diseased canes after they have been cut, that is at the mill: diseased canes in this variety are stated always to have red stripes and these are entirely absent in healthy plants. But, ordinarily, one must depend on the blotching of the leaves and therefore make the selection for planting before cutting the canes. It would, moreover, be much the wiser course to secure healthy seed from fields in which no Mosaic occurs, for there appears to be an incubation stage of two or three weeks, during which infected plants may show no trace of the disease in their leaves, although the virus has already been introduced into their systems. It is a fundamental plank in all measures at present suggested for the control of the disease, that every diseased plant will pass on its virus in its cuttings and that no healthy plant can do so. But this is only half the battle. A few diseased plants, in an otherwise healthy field, will rapidly infect the whole field once the leaves are out, for we gather that this secondary infection takes place only through the

leaves. Therefore a system of "roguing" is necessary, and it is important that this operation should be carried out as soon as the first trace of the disease declares itself, namely when the plants are quite young. It is moreover necessary to dig out the whole stool, so as to destroy all the buds which otherwise may later shoot out their leaves to carry on the infection. These dug out stools need not be burned or otherwise destroyed, for it will be sufficient merely to throw them into the middles between the rows. This sounds very extraordinary practice in a highly infectious disease, but it has been shown that wilted plants are not to be feared: we presume because the suspected insect carriers will not find any juice in their tissues and will confine their attention to the more succulent growing plants in the rows. This main factor of insect carriers has constantly to be borne in mind, and the roguing should therefore be done before they enter the field of young canes, or are present in large numbers.

An eradication campaign has been started in Porto Rico, and Earle has given the results of the first year's work in the words of those planters who have adopted his suggestions. The work was admittedly carried out with varying thoroughness, and the results obtained agree closely with this. The cost in cases of slight infection appears to have been very moderate, often under a dollar per acre, but, in cases where 30-50 per cent of the plants in the field were affected through the planting of diseased sets, it naturally was a great deal more. At first it was not intended that eradication should be attempted in such cases, but the results of the first year's work have proved so eminently satisfactory, that it is now suggested that it might be attempted in all fields, and that even such as have 100 per cent of diseased plants need not be excluded. In these cases, however, nothing can be done in the absence of a ready source of healthy seed cane, and this is of course difficult to introduce. If this source is available the infected canes should be crushed without any attempt at using them for seed purposes. Where the sound seed is insufficient to plant up the whole area of healthy fields these should be kept as far as possible from the diseased plots, and increased rapidly for seed purposes. Ratooning should be totally dicontinued in fields suffering heavily from Mosaic.

The second line of control is the introduction of immune and resistant or tolerant varieties. Unfortunately, as already stated, the only ones at present known to be immune are those of the Uba or Kavangire class, and it is for the planters to decide whether these canes are worth growing for sugar making. They are definitely inferior to the tropical canes in certain particulars and are not therefore to be recommended for general use in the tropical belt where thick canes can be grown. With regard to resistance, there is a better prospect of success. A good deal of work has already been done on the subject. We know, for instance, that all of the Java seedlings which have North Indian blood in them are highly resistant. Although readily taking the infection, the presence of Mosaic has little influence on the greenness of the leaves: the growth is good and the tonnage heavy, while the juice does not appear to suffer at all. Here again it is for the planter to decide whether they are sufficiently rich in sugar to be introduced on a large scale in place of the former more tropical varieties which have been so badly hit by the disease. But there are, among the latter

class, great differences in their degree of resistance, as has been shown by Earle in another paper. Some of these have already been mentioned, and it is desirable that this work of selection should be strenuously pushed forward, and such as have responded favorably multiplied as rapidly as possible.

These appear to be the main facts of the case regarding Mosaic at the present moment. With the amount of energy being thrown into its study, it is certain that new facts will be brought to light, and the views expressed in this article will suffer change in various particulars. But, supposing that there is no alteration in the main facts of the case, there seems to be a probability that Mosaic will be mastered in place after place, and will again take its position among the minor diseases of the cane, many of which have, in their turn, assumed alarming proportions for a time. One fact is obvious: if the industry is to be carried on successfully and such visitations are not, every now and then, to catch the planters unawares, a greatly increased attention will have to be paid to the fields in the future. It is of little use to devote exclusive attention to the factory if the source of supply is liable at any moment to be cut off.

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[L. O. K.]

The Mottling Disease of Cane and the Sugar Production of Porto Rico.*

By C. A. Figueroa.

Since the year 1915 the cane growers of Porto Rico have been complaining that the sugar production of the Island has been diminishing with every suc-

* Journn. Dept. Agr. Porto Rico, 3:35-39, 1920.

ceeding crop. About the same time it was noticed that the fields were taking a yellowish color, the growth seemed to be handicapped, the stems were beginning to shrink and crack, and finally that the cane production per acre was getting to be less and less. To the disease presenting these symptoms was given the name of "matizado" or mottling disease.

A great many efforts have been made to control this disease, but so far they have proved to be of little value. Today every cane-growing section of the Island is more or less infected.

About a year ago the students of the disease stated that the infection was "very general in the cane fields to the west of a line drawn from Bayamón on the north coast down to Guánica on the south coast." Only isolated cases were found to the east of this line. The progress of the disease since then is best shown by the following letter:

"My Dear Mr. Figueroa:—

"In reply to yours of September 8, inquiring about the present extent of infection with *matizado* in the different cane-growing districts, I would say as follows:

"From Bayamón to Barceloneta on the north coast infection is as yet only partial, but the disease is sufficiently abundant to constitute a commercial factor of importance. Your investigation will probably show some effect of the disease in lessening production in this district. As a rule the hill lands are more heavily infested than the *vegas*.

"From Arecibo to Central Coloso on the west coast the per cent of infection is considerably heavier than in the first district, but it is not total in all the fields, especially near the coast. Back in the hills the infection is very severe and very many hill fields have been abandoned.

"From Rincón around the west coast to San Germán the infection may be considered as total. Many of the fields are actually 100 per cent infested and very many over 90 per cent infested. It is doubtful if any field can be found that is not more than 50 per cent infested.

"From San Germán to Peñuelas the infection is very general and is now spreading more rapidly than in any other part of the Island. It is not yet, however, as complete as in the western district.

"At Central Mercedita near Ponce and in the fields about Juana Díaz there is considerable infection, but in the remainder of the south coast from Ponce to Patillas while the infection occurs locally at many places there is as yet too little to be a commercial factor.

"The same can be said of the entire east coast, though local outbreaks have occurred at Naguabo and Fajardo.

"Cayey is heavily infested.

"The district from Caguas to Juncos is partially infested, but not sufficiently as yet to affect total yields very seriously.

"There is also a local outbreak at Trujillo Alto which extends to the neighborhood of Carolina.

"The above data, in connection with the other statistics you have gathered, should show quite conclusively the actual losses due to the *matizado*. I shall be very much interested to see your conclusions.

"Yours truly,

"(Signed) F. S. Earle,
"Expert in Cane Diseases."

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It will be noticed that the cane-growing zone of the Island has been divided according to Professor Earle's letter. A glance at the statistics will show that where the infection is most intense the sugar production has diminished most heavily.

The first section, which Professor Earle calls partially infested, (first zone) increased its acreage by over 4400 *cuerdas* in 1918, nevertheless its sugar production was diminished by 2850.31 tons. This figure represents 4½ per cent of the 1917 crop for the zone. The following year the acreage was diminished by over 450 *cuerdas* and then the loss of sugar goes up to about 18.3 per cent of the 1917 crop. It will also be seen that there is no proportion between the fluctuations in acreage as compared with the sugar output.

In the section from Arecibo to San Sebastián the infection is still greater than in the preceding one. Of this section Dr. Blouin of Louisiana says the following:

"In the district between San Pedro and Mayagüez, particularly in the Arecibo district, the damage has been very extensive. I visited three or four plantations in that district and the damage amounted to 40 per cent of the crop."—(La. Planter and Sugar Manufacturer, Oct. 18, 1919.)

The statistics show that this section has seen its sugar production reduced by about 40 per cent in two years.

The section from Rincón to Lajas offers a conclusive proof of the extent to which this disease interferes with production. In one year the sugar output is cut down to 67.6 per cent of the normal and the next year it goes further down to nearly 60 per cent. This clearly shows the rapid progress of the disease in one year.

This has been partly due to the fact that seed has been very scarce in that section and lots of diseased seed have been used. These could be bought at very low prices. The writer in his report on a trip throughout this section was informed of this fact:

"The fact that cane seed (cuttings) are being sold at a very low price in the San Germán valley induced me to look into the matter somewhat carefully. After some investigation I found healthy seed was exceedingly scarce in that section and this led many planters to use diseased seed which they can get at very low prices, thus helping to spread the disease in the most efficient manner. Lots of these diseased seed have been sold to the planters at Sabana Grande."

The section from Sabana Grande to Peñuelas has lost considerably. In this district, as in the first one here discussed, the infection has increased very rapidly and the losses in sugar have also increased accordingly.

In the south and east coasts of the Island the disease is only beginning to show. Losses here are greatly due to the lack of rainfall.

All students of this disease agree that its attacks are more severe in the hill plantings than in the lowlands of the coast. The Cayey and Adjuntas section prove this conclusively.

"The disease reduces the tonnage and therefore also reduces the production of sugar per acre." This statement was made by the director of the Insular Experiment Station in his Circular No. 14, and to back up his utterance he mentions the following experiences:

A Java experiment gave these results:

Healthy cane, 21.23 tons per acre, first crop.
Mottled cane, 18.20 tons per acre, first crop.

RESULTS OF A HAWAIIAN EXPERIMENT.

	Tonnage of 3 Rows 80 Feet Long	Estimated Tonnage per Acre	No. of Canes	Average Weight per Cane (Lbs.)	Tons of Sugar per Acre
Healthy cane	2.786	101.13	835	9.27	14.98
Mottled cane	1.5495	56.24	623	8.01	8.43

Other Conditions Affecting the Sugar Production.

This work will not be complete if it does not contain a brief discussion of all factors that may have had some influence on the sugar production. The writer does not pretend to assume that every pound of sugar lost has been due to this disease. Though he firmly believes that the bulk of the loss is the result of the *matizado,* there are other causes to be taken into consideration.

Rainfall.

The rainfall records available are not complete and for this reason they do not appear in this work. However, it is a well-known fact that the severe drouths that have occurred in different sections of the Island, particularly in the south coast and in the Arecibo-Aguadilla section, have contributed to lower production. Furthermore, the scanty amount of rainfall in certain sections like the eastern coast have come just at the wrong time.

But even so, it is not reasonable to blame the lack of rainfall for the whole trouble. The precipitation records that are complete show that there is no uniform relation between production and rainfall.

Manures.

The following table [1] shows the importation of commercial manures by the district of Porto Rico during the last three years:

Year.	Tons.	Value.
1915-16	39,702	$1,735,391
1916-17	45,769	2,827,796
1917-18	40,811	2,929,726

This table shows that in the year 1917-18 the imports were cut down by 5000 tons. It also shows that the cost of commercial manures has gone beyond the reach of the small cane grower.

[1] Customs House records.

But if the small planter has not used as much commercial manure as before the war, he has used more stable manure, guano, etc. Moreover, the manure-mixing plants of the Island have increased their capacity to a considerable extent, and consequently lots of manurial ingredients have been imported. It is very probable that all of these ingredients have not been imported under the head "Manures" or "Fertilizers," but as "Chemical Products." The enormous increase of importations under this heading appears to confirm this belief.

On the other hand, these 5000 tons that were not imported last year are largely potash. All commercial manure users have missed this ingredient in their manures. This has led them to believe that lack of potash is to be blamed for the deficit in the sugar production.

However, manurial experiments on record in Porto Rico as far back as 1910 have failed to show the economic advantage of the use of potash as a fertilizer in cane cultivation. Professor Earle says in connection with the use of potash:

"Potash should not be taken into consideration, for its need is not so essential. Experiments with cane in Porto Rico show that the use of potash in these soils is of no such a great need. The demand for potash as a manure is one of the things 'Made in Germany.' Its use has been extended by means of the active propaganda of the 'German Kali Works.' For a good many years previous to the war this firm has been paying specialists in almost every agricultural country, whose business it was to work in favor of the potash." (Circ. No. 17, Ins. Exp. Sta., Recomendaciones sobre el Cultivo de la Caña en Puerto Rico.)

Tillage and Cultivation.

All those interested in agriculture in Porto Rico agree in that our methods of tillage and cultivation are rapidly and constantly improving. A trip through the cane section will convince anybody of this fact. Soils are better prepared; more attention is paid to manurial and cultivation problems; seed selection is beginning to be popular; the sight of implements such as the tractor, the harrow, the disc plow and others is familiar nowadays; and, in short, the sugar men are beginning to realize that sugar cannot be made in the factories if proper attention is not paid to the agricultural end of the sugar business.

Comparing the acreage with production for the last three years we have—[1]

Year	Cane Acreage (Cuerdas)	Total Sugar Output (Tons)	Tons of Sugar per Acre	Per Cent Decrease
1917	205,106	503,081.18	2.41	....
1918	256,431	453,975.55	1.77	9.7
1919	238,901	406,000.00	1.70	19.0

[1] From Bureau of Property Taxes and Report of the Treasurer.

This means that, taking the crop of 1917 as a basis for calculation, Porto Rico has lost 146,186.81 tons of sugar in two years. This is about equal to 30 per cent of its normal production for one season. The figure is large enough to command some attention.

[L. O. K.]

Infection and Nature of the Yellow Stripe Disease of Cane (Mosaic, Mottling, Etc.).*

By J. Matz.

Introduction.

In December, 1918, the writer began studies of this disease in Porto Rico. The following is a summary of experiments and histological studies made during a period of twelve months. Owing to the conflicting views among investigators regarding the nature of this disease there could not be obtained much guidance as to any one definite line of investigation to follow out, so that even previous experiments carried out by others had to be repeated in order to gain a clear path for any line of investigation.

In reviewing the literature on this disease it was found that although the disease has been recorded to have appeared in cane fields which were previously known to be free from any visible signs of it, yet there is hardly any records of exact observations of its transmissibility to known healthy plants. There is no doubt that a large part of the spread of the disease is due to the use of infected seed, but it is also an undeniable fact that new or secondary infections occur. This is supported by records of observations made in Porto Rico, Java, Hawaii and Cuba. It would be erroneous to assume that healthy cane showing new cases of yellow striping had in actuality the disease in such a dormant state as not to show its symptoms up to a period of several months or more. Tests as to dormancy were made, at the beginning of this work here, with seed pieces from cane which were in a not advanced stage of the disease. Portions of these canes were cut into pieces having one or two eyes each and placed in glass moist chambers for germination. The cane and glass chambers were sterilized to remove molds and bacteria. In forty-five trials, using cane from three different sources, not a single case was found where the symptoms of the disease were not observable in the unfolding leaves in the shoots of diseased seed. Diseased seed always produced diseased plants; in other words, if the disease is present in the cane it will show up at an early stage in the leaves, by its characteristic symptoms. Further tests along this line were made by planting diseased seed pieces in sterilized and unsterilized soil, in pots. Here the results were the same only with a slightly higher accentuation of the symptoms in unsterilized soil due to the fact that the seed piece breaks down quicker by the aid of ferments and fungi which sometimes abound in such soils, thus aiding in the stunting and deterioration of the young buds. In the unsterilized soil the young shoots became, in addition to the yellow striping, speckled with a reddish tinge, and formed a shorter stem with the leaflets growing in more or less of whorls.

There is the possibility of the symptoms being so faint as to evade detection to the casual observer. The various symptoms of the disease on different varie-

* Jour. Dept. Agr. Porto Rico, 3:65-82, 1920.

ties of cane have been described in previous publications, and it is plain that the disease can be recognized in all instances. However, the writer had under observation four plants in pots which showed only an occasional thin stripe of a darker green on a field of lighter green. These plants were kept up in good condition, having applied to them a liberal amount of nitrate with frequent watering. The symptoms of yellow stripe always existed in these plants in the older canes, but in a rather less pronounced form. The young shoots, however, which occasionally come up at the bases of these canes show the symptoms more distinctly. Other plants, diseased, and growing under the same condition close to the above show the disease very clearly and distinctly. On the other hand, the same variety, Crystalina, is known to produce clearly distinct symptoms upon its becoming diseased in the field. The above four plants are kept for further observations. A degree of severity exists in the different fields and in individual cane plants. The severity of the disease depends, as has already been observed by others, on varietal resistance, length of time the disease is propagated in a given plant, and local conditions under which the cane is growing. In an infection experiment conducted in the greenhouse of the Insular Experiment Station, mention of which was made in last year's report, the "canker" stage was observed to have occurred in a cane in three months from the time when the first signs of the disease were noticed. This is contrary to views held by others, i. e., that it takes a certain number of generations for the canker stage to arise. It was really the general unfavorable conditions for the growth of the plant, as it was grown for almost a year in a five-gallon tin can, that helped the canker stage to be shown up sooner.

Infection Experiments.

I. *Contact.*

During the first part of this year experiments such as have been tried by others have been repeated in order to gain an intimate knowledge of the behavior of the disease. Healthy and diseased plants were planted together in the same pots; healthy and diseased seed pieces were split in half, and then a diseased half and a healthy half were fastened together and planted. There were no transmissions of the disease to the healthy plants. The healthy plant, though in contact with the diseased plant, has not contracted the disease. The healthy seed produced healthy shoots right alongside the diseased seed and shoots in the same pot. Healthy seed pieces were watered with water in which diseased cane was allowed to stay for some time. No infection occurred.

An experiment was made to find out if the disease could be transmitted through the roots. Diseased tissue was fastened onto the root eyes of healthy seed, so that the growing rootlet may come in contact with the cut surface of the diseased tissue. Eight of the healthy seed pieces germinated and the shoots were healthy. After four months in the pots two shoots of the healthy seed showed symptoms of yellow stripe. The experiment was repeated but gave negative results. The fact that the symptoms were belated in showing up would indicate that the two plants became infected through another source. There were diseased cane in the greenhouse.

Another experiment was made in the following manner: Healthy and diseased seed pieces were cut to contain three dormant buds each. The middle buds were carefully cut out with a sharp knife. Care was taken to make the cut at least one-half inch on all sides from the bud, in order to leave uninjured root eyes and some tissue for the growth of the bud. The buds from the healthy seed were then inserted in the diseased seed in the places of diseased buds and the buds of the diseased seed were inserted in the healthy seed. Practically all of the buds germinated and from the first no transfer of the disease was observed to have taken place either in the healthy seed with the diseased buds or in the healthy buds inserted in the diseased seed. The grafts thus made did not live long, but the seed in which they were inserted developed sound shoots from their original two remaining buds. It was thought that by bringing in contact the cut ends of the vascular systems of diseased and healthy cane a transmission of the disease might take place. But no infection occurred in this experiment.

II. *Juice.*

Experiment 1.—On April 16, an experiment was made in the following manner: Five cane plants of about 8 months old, growing in five-gallon tin cans in the greenhouse of the Insular Experiment Station were examined and found free from any symptoms of yellow-stripe disease. Each of these plants consisted of one single stalk of about one inch in diameter and averaging about three feet in height. At the bases of each were one or more shoots of about six inches in height. These shoots also were free from yellow-stripe disease symptoms. The five stalks were cut back leaving stumps of about four inches above ground, the shoots were left as they were. Juice from a yellow-striped piece of cane was pressed out and injected, with a hypodermic needle, into the stumps near the surface of the ground. On April 28 typical symptoms of yellow stripe was observed in the lower parts and along the midribs of the central leaves of two shoots in two out of the five pots. At first only a few, larger, light green, narrow areas were noticed; later these light green areas spread all over the leaves and they became patterned with short alternating light-green and green stripes. In one of the two pots which showed infection on the 28th of April there were two shoots at the base of the old stalk but only one shoot showed infection on that date; however, about a week later the other shoot became infected. In three months the infected stalks have become more or less shrunken at the internodes and showed typical cases of the "canker" stage. The other three plants remained free from the disease throughout the experiment, which lasted ten months. In this and later experiments the positions of the plants were noted and they were kept in the original places throughout.

THE POSITION OF PLANTS IN EXPERIMENT 1.

	Plants inoculated April 16				
	No. 1	No. 2	No. 3	No. 4	No. 5
April 28	free	diseased	free	diseased	free

Experiment 2.—On May 1 a similar experiment was made in the same greenhouse with similar plants. Twenty plants were inoculated with juice from diseased cane and 20 were left uninoculated as checks. On May 14 two of the inoculated plants showed the symptoms of the yellow stripe disease. These plants are marked "D" in the next table.

The positions of the pots in this experiment were thus:

Bench 1:										
Inoculated	1	2	3	4	5	6	7	8	9	10D
Check	1	2	3	4	5	6	7	8	9	10
Bench 2.										
Inoculated	1	2	3	4D	5	6	7	8	9	10
Check	1	2	3	4	5	6	7	8	9	10

Experiment 3.—On the same date as the last experiment 10 plants were cut back only a little above the growing point; 5 of these were inoculated in the cut surface of the top by injecting diseased juice with a hypodermic needle, and 5 were left as checks. All of these have remained free from the disease.

Experiment 4.—On May 2, 25 healthy stools about three months old were transplanted from the field to the greenhouse in pots. The plants were cut back as in the first two experiments, and 8 of these were inoculated with diseased juice and tissue; that is, in addition to the injection of juice, pieces of diseased cane were forced into small holes in the stems. All 25 plants remained free up to October, when one of the checks developed the yellow-stripe disease symptoms. It must be stated that the four plants which developed the disease in the first experiments were of a lot of cane which were more mature than the last 25 plants. In order to test this point 18 seed pieces of mature Crystalina cane were cut to one or two eyes, 12 of these were inoculated near the base of the bud, by boring a hole into the seed piece three-quarters inch deep and directly into it was pressed juice from diseased cane, and 6 were inoculated in the same way with healthy cane juice. All were planted in pots and placed in the greenhouse.

Experiment 6.—At the same time 35 Crystalina stools in a field that has just been cut were inoculated with juice in the stubble near the bases of sprouting buds. In both of these last two experiments not a single positive case developed. The plants in the pots were transplanted, after four months in the greenhouse, to an open field, and up to the present no signs of the disease have become visible.

Natural and Secondary Infection.

Experiment 7.—During the time when the above experiments were made there has not come to the writer's notice a case of secondary infection in the greenhouse, nor were there any such cases reported previously. This was rather strange, as secondary infections were being picked up every two or three weeks in the adjacent cane fields. The greenhouse was not "insect proof." In order to make sure that secondary infections do occur in known healthy cane, 48 seed pieces from three healthy and mature Crystalina canes were planted in pots and placed in the greenhouse. After two months from germination three of the 48

showed symptoms of yellow-stripe disease. However, these three plants, together with a number of others of the same lot, were on the ground instead of on a bench.

Experiment 8.—So another series of 50 seed of three healthy white Otaheita cane were planted in pots and all were placed on clean benches. In about three months from germination one of two shoots from two separate seed pieces in the same pot became distinctly diseased.

Experiment 9.—Ten cane stools having been cut back and transplanted from the field to pots in the greenhouse have been allowed to grow for four months. These showed no signs of yellow-stripe disease during that period. At the end of four months they were cut back and allowed to sprout again. One shoot began to show yellow-stripe disease in the unfolding leaves, and in two weeks the entire stool became diseased.

Experiment 10.—On May 15 five healthy stools in five pots were inoculated with diseased juice in the stalks near the root crowns. Up to September no symptoms of yellow-stripe disease have developed. During the first part of September the plants were all cut back and allowed to sprout up again, and two plants began to show the yellow-stripe disease in the central unfolding leaves of their shoots. It is assumed that these were secondary infections. It is of interest to note the development of the disease in one of these pots.

The position of the row of pots on the bench was thus: 1 2 3 4 5.

Numbers 2 and 5 became diseased. No. 5 had two small *cepas* of 5 to 7 shoots. Both *cepas* came out from two original buds on the sides of a single seed piece. At first one *cepa* showed the disease, the symptoms of yellow stripe appearing first in one shoot and then in another until all became visibly infected. In about three weeks the second *cepa* became diseased, and again a gradual spread of the disease from one shoot to another was observed. In all of these shoots the central leaves always showed the symptoms first. It appears that the disease gradually communicates from one shoot to another through a common channel.

It is quite certain from observations made on healthy and diseased plants grown in close contact with one another, that mere surface contact does not transfer the disease to healthy plants. In the greenhouse a row of 10 diseased plants were placed alongside of a row of 10 healthy plants, allowing for contact between the healthy and diseased leaves, and not a single case of new infection resulted. However, during the late part of the summer a healthy plant which was adjacent to a diseased one in the greenhouse became diseased. This is the first case of its kind in the greenhouse; its occurrence should rather be layed to an outside agent rather than to its being close to a diseased plant.

The occurrence of yellow stripe in the greenhouse has been in all features similar to the way it works in the field. It attacks the young shoots and it is sporadic in location; it picks out a plant here and there only, and there is not a general spread taking in complete areas. In the field a new infection may sometimes be observed on large cane, but from personal and close watch of the plants

in the greenhouse secondary infection on more or less grown cane has not been seen.

The following conclusions can be drawn from the above observations: first, that healthy cane from healthy seed became infected with the yellow-stripe disease; and secondly, that the disease has been transferred artificially to healthy plants in four cases at least. It should be observed that in both, Nos. 1 and 2 experiments, the disease showed up in about two weeks from inoculation and there were no other new infections in the other plants in the greenhouse at that time. However, the exact method to insure takes is not known as yet. The prevailing idea that insects are the carriers of this disease is highly plausible, but the writer has not taken up this phase of the problem.

Histological Studies.

Histological studies of yellow-striped cane were made with the view to determine if possible in what way the disease affects the tissue of the host. A search for abnormalities in the interior of the cane stalk and leaves of diseased plants was made. Tissue from diseased mature cane stalks, from underground parts, from growing points and from leaves were cut with a sharp razor free hand and with the microtome. In studying microscopic sections of the outer cankered tissues of yellow-striped cane it was noticed that sometimes the parenchyma as well as collenchyma cells of the discolored areas possess very distinct, single, spherical, darkly colored and dense protoplasmic bodies. At first glance these resemble spore bodies of some organism. (Fig. 1 *a, b.*) These bodies were also

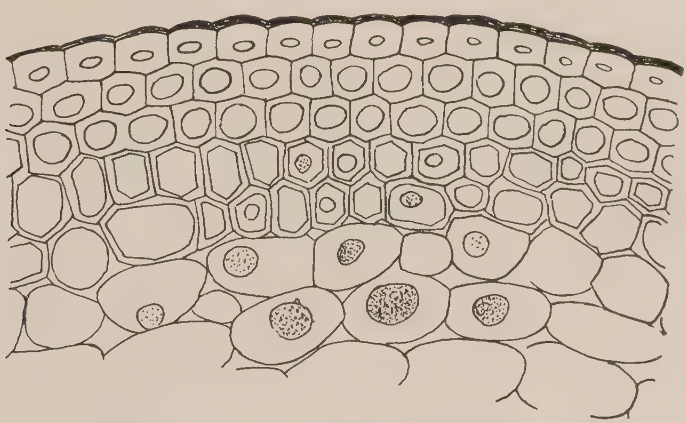


Fig. 1a. Dense and deeply-colored nuclei in cane tissue near the rind. Drawing of a free-hand section from a yellow-stripe diseased stalk. (× 150.)

found in the center of diseased cane. In searching in the tissues of non-yellow striped cane it was found that these bodies also exist in parenchyma cells there. It was found in the base of a young stalk which was injured by a mechanical agent, it was found in the cells of roots of non-yellow striped cane and in the injured part of a stalk of cane of the same nature. It seems clear enough that under certain conditions of growth the nuclei of certain cells become dense

and deeply colored and give the appearance of dense granulation when influenced by an inhibitory or injurious factor. Sections of tissue containing the spherical bodies referred to above could not be permanently mounted in the usual way as alcohol dissolves those bodies. When placing a free hand section in alcohol the spherical bodies become vacuolated and ultimately disappear from view, only a very thin wall being left.

Paraffin sections of the uppermost nodes of yellow-striped and healthy cane were made. It was observed that a difference in the appearance of their respec-

Fig. 1b. Drawing of similar bodies as in Fig. 1a, in cells of non-yellow-stripe but otherwise injured cane tissue. (× 250.)

tive tissues existed (Figs. 2, 3, and 4). In the diseased tissues some of the parenchyma cells between the fibro-vascular bundles were filled with a protoplasm which was dense and finely granulated, the bundles showed apparently the same substance in the sieve tubes and vessels,[1] while in the cells of the healthy

[1] The writer has of late seen specimens of cane affected with gum disease due to *Bacterium vascularum.* This disease is distinctly different from the yellow-stripe disease, the gum of the former is yellow and full of bacteria which are easily cultured. No slimy exudation occurs in yellow-stripe disease.

cane the fibro-vascular bundles were free and the parenchyma between the bundles contained scattered and coarser granules. The last named are common in cut and exposed portions of young growing parts of cane.

Leaves of about the same age of healthy and yellow-stripe cane were studied. Figures 5 and 6 show a striking difference in the appearance of the two. The healthy leaf in cross section shows no abnormality except slight shrinkage; in the diseased leaf some of the epidermal cells, especially near the stomata, and some internal cells show dense contents which is colored slightly brown, and which is similar in appearance to the abnormalities found in the cells of the cane stem. It seems that a foreign plasmodium-like substance is apparently present in the cells of the yellow-striped cane leaf and stem tissue.

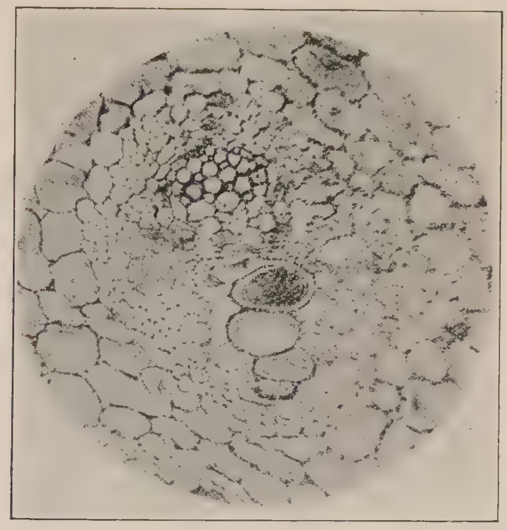


Fig. 2. Photograph of a vascular bundle from near the growing point of yellow-stripe diseased cane, showing the finely granular substance in the vessels. (× 50.)

Further research along this line revealed the presence of the above plasmic substance more constantly and in a more defined form in "cankered" cane stalks. In investigating the histology of "cankered" cane a feature, which has not been mentioned before in the literature on the subject, has been noticed. Cankers have been characterized as exterior symptoms consisting of a few outer layers of deteriorated cells, but in reality one may find separate and distinct pockets of brown to reddish-brown tissue deep in the interior throughout cankered cane. More often such a discolored region may be found in the form of a short streak, several centimeters in length, usually very close to the rind of the stalk, but these streaks are not always exposed as they are found even where no breaking of the outermost layers of cells has taken place. Together with these distinctly brownish-colored areas there may also be present in the interior of stalks small

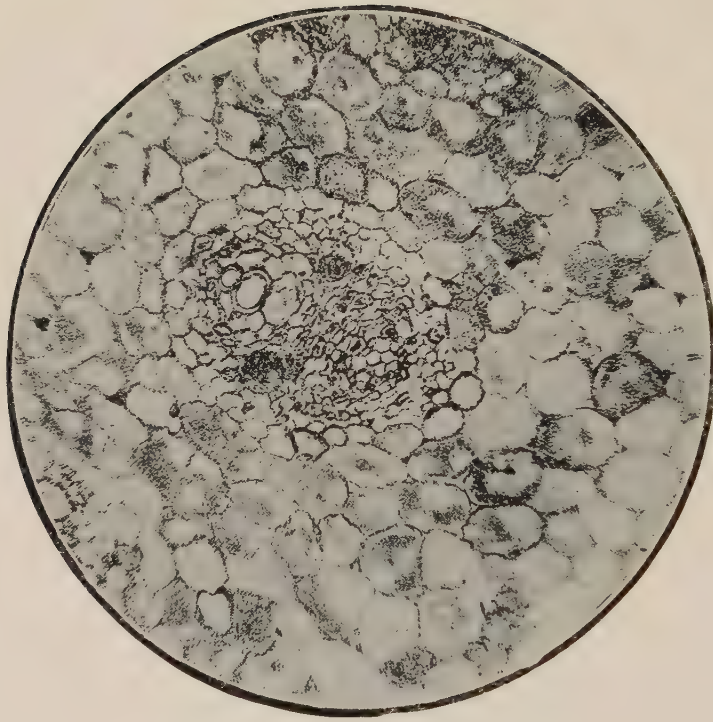


Fig. 3. Photograph of a cross-section through a growing point of yellow-stripe diseased cane. Note the character of the parenchyma cells and compare with Fig. 4.

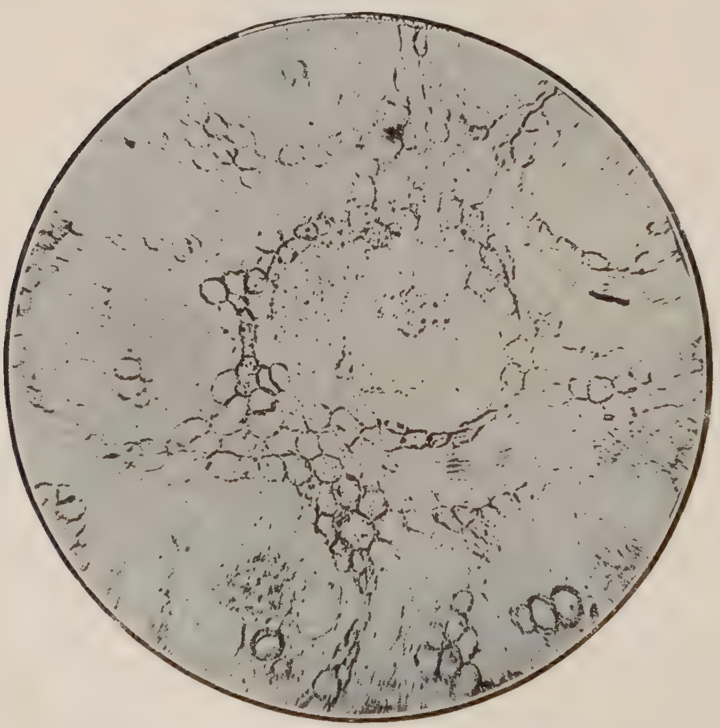
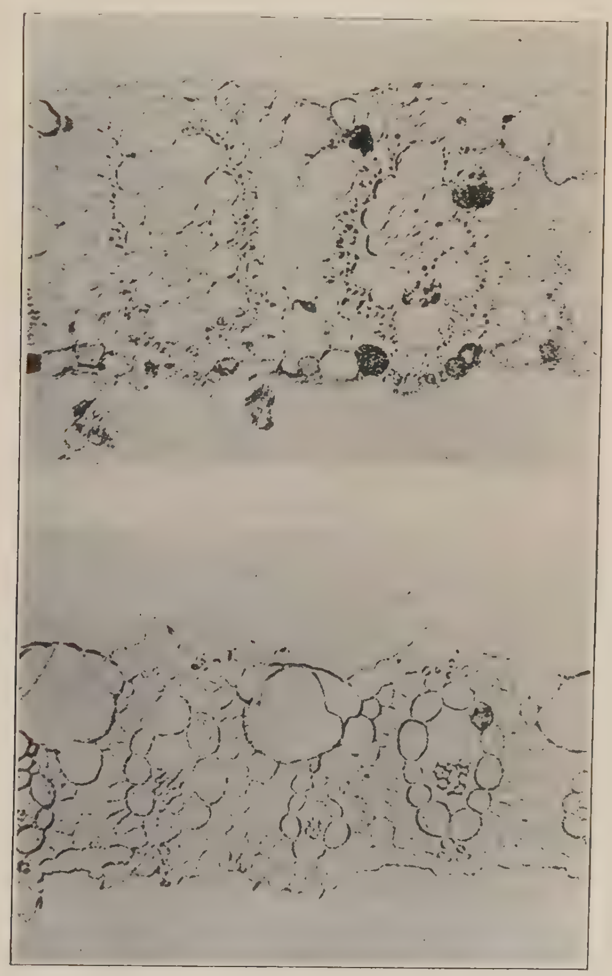


Fig. 4. Photograph of a cross-section through a growing point of a healthy cane stalk. (× 50.)

longitudinal and light-colored areas where the parenchyma cells have entirely collapsed and leaving an empty cavity of a millimeter or more in width and of variable length. Microscopic sections of the discolored areas in yellow-striped cane stalks show that some parenchyma cells are full of a more or less hardened or compact, densely but finely granulated, and slightly browned plasma. (Fig. 7.) Usually there are small groups of a few cells thus filled, but it is not uncommon to find only a single cell (Fig. 8) full of the granular material while the sur-



Figs. 5 and 6. Upper figure is a photograph of a cross-section through a yellow-stripe diseased cane leaf. The lower figure is a photograph of a cross-section through a healthy cane leaf. (× 100.)

rounding cells only show a slight brownish discoloration in their walls. This phenomenon is common in older portions of more or less full-grown cankered cane, especially where an alteration in color exists in the stem tissue. It has also been observed in leaf sheaths of yellow-stripe diseased cane. Here it is found in slightly depressed areas on the inner side of apparently uninjured leaf sheaths.

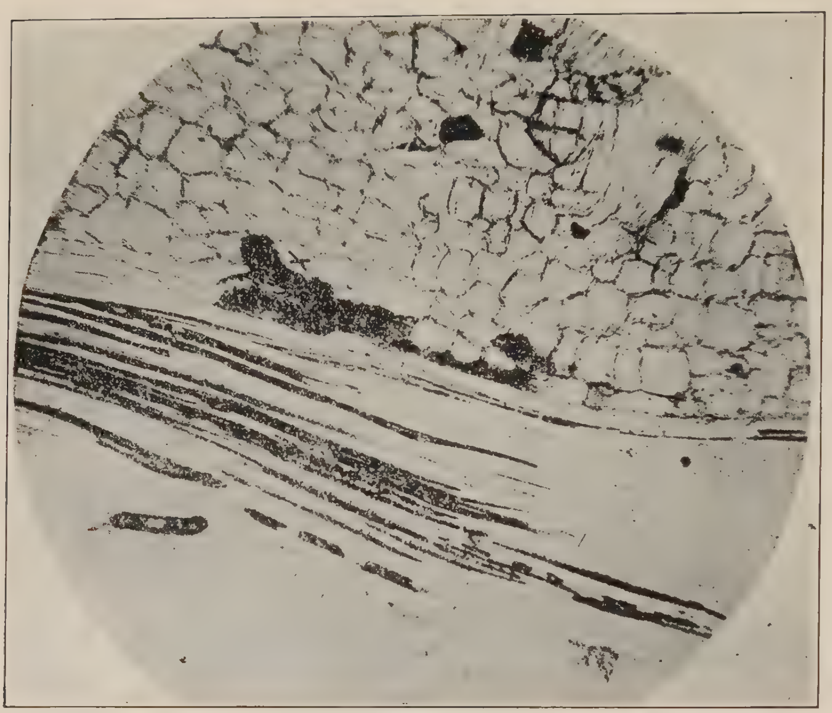


Fig. 7. Photograph of a longitudinal section through a node of yellow-stripe diseased and cankered cane, showing a group of plasma-filled cells at X. (× 50.)

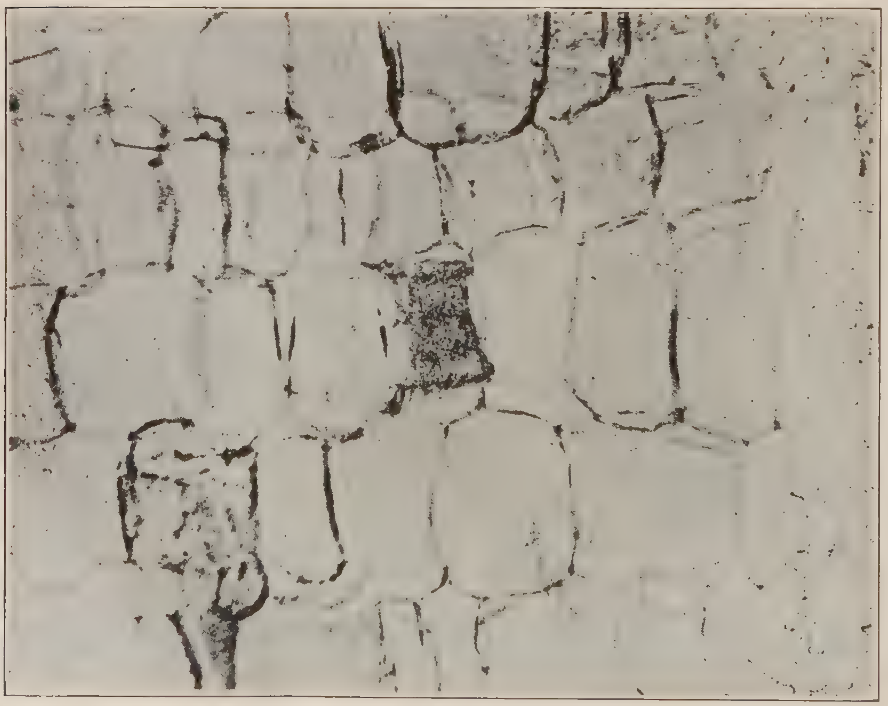


Fig. 8. Photograph of a section through an interior canker of yellow-stripe diseased cane, showing in the center and near the lower left-hand corner single cells filled with finely-granular plasma. (× 250.)

It seems that the plugging of parenchyma cells in this manner is a diagnostic feature peculiar to yellow-stripe disease.

Free hand sections and sections from tissue which was fixed and killed and imbedded in paraffine, from internal portions of cankered cane, were treated in the usual way, *i. e.*, dehydrated with alcohol and cleared with xylol. The cells which contained the dense and finely-granulated substance did not lose it in the process of mounting.

In examining these sections with the microscope it is at once apparent that

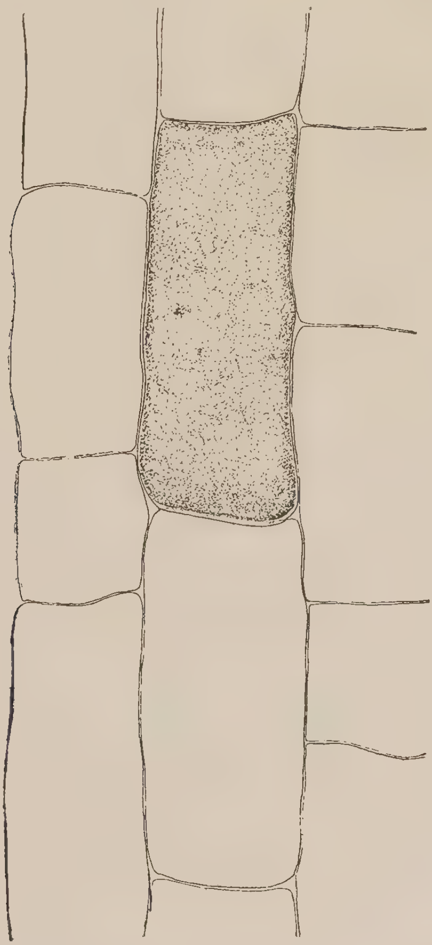


Fig. 9. Camera lucida drawing of a plasma-filled cell in an internally discolored area in yellow-stripe diseased cane stalk. (× 333.)

the granular substance is made up of a mass of small hyaline bodies more or less uniform in size. However, their exact size and form could not be ascertained, due to the fact that the whole mass is in the form of a compact plasma. The hyaline bodies which are dotted throughout the mass are less than one micron in length in sections from freshly cut cankered cane. They more nearly resemble nuclear granules in a mass of cytoplasm. They are less clearly defined than masses of bacteria.

Early attempts to induce growth development in agar from the above plasma-filled cells have failed. It was thought advisable to observe the condition of cankered cane in more than one stage. Therefore such cane was collected from three different parts of the Island,—south coast, north coast, and northeast sec-

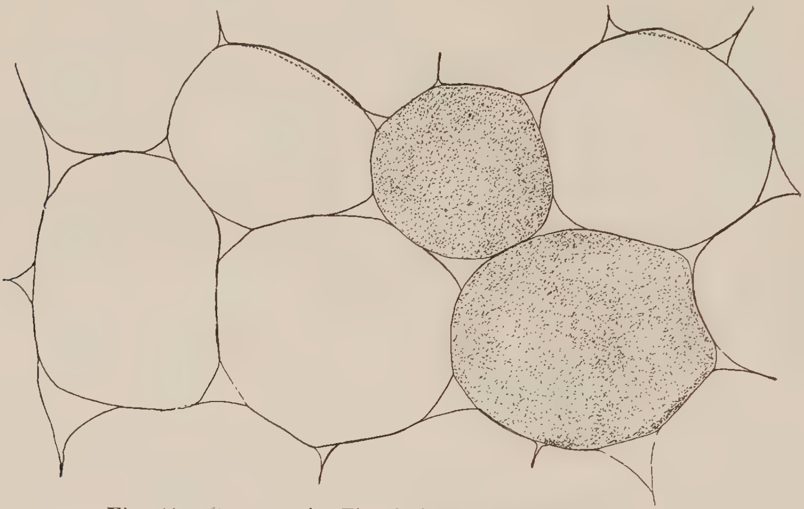


Fig. 10. Same as in Fig. 9, in cross section. (× 333.)

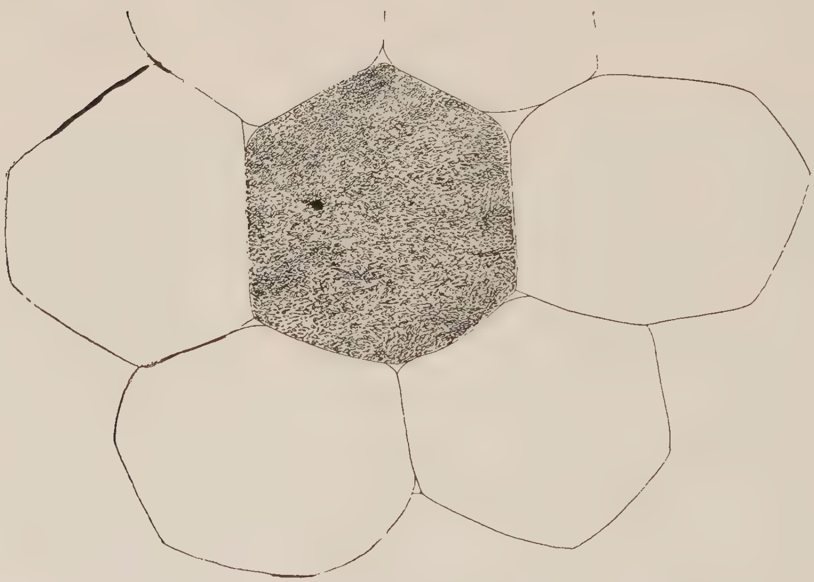


Fig. 11. Drawing of a section of yellow-stripe diseased cane tissue two months after the cane was cut. (× 400.)

tion. The local and scattered plasma-filled cells were found in the cane from the three parts mentioned and in the varieties Rayada, Cavengerie or red cane, and other kinds. In growing cane the condition of the plasma-filled cells were similar in all canes examined. Some of the cankered cane was kept in a covered chamber for two months, so that the cane became devitalized and yet not much

dried out. Free hand sections of this material showed the granular plasma material in the parenchyma cells in the same proportion as in freshly cut cane, but the granules in the former were more distinct, irregular in form, elongated and somewhat larger. In addition rotary movement of the individual minute bodies within the host cells was distinctly noticeable. It appeared that growth or a separation into more distinct individuals took place. It was very clear from the material at hand that the compact plasma in the cells of freshly cut cankered cane were in every way similar in appearance and distribution to the plasma in the cells which were seen in the more devitalized cane, only that in the latter more distinctness was observable. However, it was felt that sugar-cane treated in this manner is bound to become overrun with microorganisms and so more cankered cane was obtained, sterilized in bichloride of mercury and kept in the moist chamber for daily observation. It was found that in the course of two days some cankered cane showed a greater distinctness in the granulation of the characteristic plasma-filled cells, and that after eight days motility was observed in the plasma mass. As to the exact nature of this organism in the cankered cane cells nothing more definite can be said until more data are obtained in the process of investigation.

In cane otherwise diseased or injured by borers or fungi a reddish discoloration usually is found, but it is more or less continuous and is confined more to the vascular bundles. Such bundles often contain a homogenous gummy substance which is not at all like the substance in cankered cane parenchyma cells. Discoloration of parenchyma cells in non-yellow striped cane may also occur, but the discoloration is not of the same character as in yellow-stripe disease tissue. In cane diseased because of an invasion of fungi or other destructive agents the discoloration is more confined to the phloem and vessels and to the cell walls of parenchyma. A red phloem and gummed vessels are signs of wilt and decay due to fungi, bacteria, insects or mechanical injury. A continuous cavity in the pith or center of the stalk is a common effect of fungus invasion.

Further work is being done and planned with the view to clear up some of the phases of the problem of yellow-stripe disease.

From a study of the internal structure of cankered cane it is clear that actual deterioration and breaking down of cells in the interior of cane in an advanced stage of the yellow-stripe disease takes place. This effect is due to no other cause than to the destructive action of the infective substance of yellow-stripe disease, as there is apparently no connection between these interior sick cells and other outside mechanical or organized agencies. Furthermore, this substance, resembling a *Plasmodium*, in some of the interior cells was found to be constantly associated with yellow-striped cane in an advanced stage of disease.

[L. O. K.]

The Mosaic Disease of Sugar Cane Order, 1920.*

Order under Section 4 *of the Protection from Disease* (*Plants*) *Law,* 1915 (*Law* 3 *of* 1915).

Whereas it is provided by Section 4 of the Protection from Disease (Plants) Law, 1915 (Law 3 of 1915), that it shall be lawful for the Governor from time to time by Order to be published in the Jamaica Gazette to prescribe the measures to be taken for the treatment of any infectious plant disease by the owner, occupier or person having the charge or management of any land, whether the land shall or shall not have been declared to be infected or suspected of being infected with plant disease and generally to make provision for the purpose of preventing the introduction and spread of plant disease or of any particular plant disease named in any other Order;

And whereas the Mosaic Disease of Sugar Cane is a plant disease which the Governor in Privy Council has declared to be an infectious plant disease and notice of such declaration has been published in the Jamaica Gazette;

Now therefore, the Governor is pleased to order and prescribe as follows:

1. The Occupier or other person having the charge or management of any land on which there are Sugar cane plants infected with the Mosaic Disease of Sugar Cane, whether the land shall or shall not have been declared by order published in the Jamaica Gazette to be infected or suspected of being infected with plant disease, shall take the following measures for the treatment of the said Mosaic Disease of Sugar Cane:

(A) *In the case of diseased stools of Sugar Cane in plants and ratoon cane fields established before the* 15*th September,* 1920, *or within three months thereafter.*

(A) 1. If less than ten per cent of diseased stools are present in a young plant or ratoon cane field where the period of growth of the sugar canes has been less than four months, the affected stools shall be pulled out or dug completely and allowed to wither and die.

(A) 2. If the number of diseased stools amounts to or exceeds ten per cent in any cane field the treatment as prescribed in Rule 1 supra shall not be enforced.

(A) 3. If the canes affected with the disease are of four months' growth or more, Rule 1 supra shall not apply.

(A) 4. No cane tops or other seed-pieces from cane fields affected with disease to an extent in excess of ten per cent shall be removed from any such cane fields for the purposes of planting after the publication of this Order.

(B) *In the case of diseased stools of sugar cane in plant and ratoon cane fields which have been established after the* 15*th December,* 1920.

(B) 1. All diseased stools in young plants or ratoon fields of sugar cane of less than four months' growth shall be pulled out or dug out completely and left to wither up and die.

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* This "Government Notice" is interesting in that it shows the methods by which they propose to control Yellow Stripe disease in Jamaica. It reached us in the form of a hand-bill.

Provided that in any case where the incidence of disease is in excess of one diseased stool per ten stools in any cane field the owner or occupier shall be entitled to appeal to the Director of Agriculture, who shall decide what treatment, if any, shall be carried out.

(B) 2. Rule A. 4. (supra) as to the removal of canetops or other seed pieces from infected fields shall continue to apply at all times during the existence of this Order.

DEFINITIONS.

In this Order the term "*Established*" shall be taken to mean that the oldest shoots of sugar cane in the field are not less than six inches in height.

"*Diseased stool*" means a stool of sugar cane with one or more diseased shoots or stalks arising either from a single seed-piece or from one root of a ratooning sugar cane. The age of a field of young plant-canes shall be reckoned from the time when the planting of the seed-pieces was completed.

The age of a field of young ratoon canes shall be reckoned from the date when the cutting of the previous crop was completed.

If these dates have not been recorded, the age of the plant or ratoon canes shall be determined by an Inspector of Plant Diseases.

2. This Order may be cited as "The Mosaic Disease of Sugar Cane Order, 1920."

3. The interpretation Law 1900 (Law 9 of 1900) applies for the purpose of the interpretation of this Order in like manner as it applies for the purpose of the interpretation of a Law.

L. PROBYN, Governor.

King's House,
Jamaica,
15th September, 1920.

2. His Excellency also directs the publication for general information, of the following description of the Disease:

Description of the Mosaic or Mottling Disease of Sugar Cane.

Cause:—The disease is due to an invisible virus (probably an ultramicroscopic organism) which infects the growing points of the shoots (probably carried by insects) so that all the leaves and all the joints and buds, developed thereafter, are infected. If such infected stalks are planted, the disease will always show in the young shoots (primary infection).

The virus can be carried through the air, from such diseased plants to the growing points of healthy plants (secondary infection).

There is no evidence yet that the disease is transmitted by the soil.

Symptoms:—To detect the disease, the young leaves in the hearts of shoots or stalks of any age should be examined. If pale green or yellowish green blotches or broken stripes are present on a normal dark green ground, or dark green blotches or stripes on a pale green or yellowish ground the disease may be concluded to be present. If the infection is primary (in the seed-pieces of plant cane or in the root-stock of ratoons) the leaves frequently show opaque white spots and stripes in addition to the other symptoms. In many varieties, the white markings on the leaves in primary infection are accompanied by white stripes on the joints. A diseased stool can usually be detected from a distance of twenty yards or more by its pale color.

The symptoms on the leaves should not be confused with pale spots due to fungus (which become brown or dead at the center) or numerous minute flecks, due to puncturing insects, nor with chlorosis or blanching, in which disease the pale stripes extend throughout the whole length of the leaves or the latter are entirely white.

[L. O. K.]

Mosaic Disease of Corn.[1]

By E. W. Brandes.[2]

Distribution

In connection with an investigation of the mosaic disease of sugar cane, a similar disease of corn has been observed by the writer on several occasions in widely separated regions.[3] On April 18, 1919, corn of an unknown variety was seen to be affected with typical mosaic symptoms in a field just west of Peñuelas, P. R. The percentage of affected plants was small, however, only 20 individuals being found in the field of some 5 acres. The corn averaged about 24 inches in height at this time and was planted between rows of sugar-cane stubble which had not been completely killed out in preparing the land for the corn. All the sugar cane was affected with mosaic. In July, 1919, corn of the White Creole variety was seen at the Sugar Experiment Station, New Orleans, La., in which the same condition was apparent. This corn was more than half grown, and the typical streaking of the leaves was somewhat obscured by certain leafspot diseases, among them the leafspot caused by *Physoderma zeae-maydis,* by which the corn was severely attacked. About 10 per cent of the plants in the field were affected with mosaic. In adjoining fields of sugar cane nearly 100 per cent of the plants were affected with the sugar-cane mosaic. In 1920 corn of the same variety was examined early in the season, and a much more serious infestation was found. The corn had been planted following sugar cane, and occasional diseased stools of the latter not killed by the plow were found all through the corn field. More than 30 per cent of the corn plants were affected. The cases were more abundant in the vicinity of the sugar-cane stools referred to above, but cases could be found many rods from any living cane. Of course, it is possible that a stool of cane had sprouted between the rows in such a situation and later had been killed by the cultivator. In May, 1920, identical cases of mosaic were seen in a field of corn near Cairo, Ga. As in the cases reported previously, a neighboring field of sugar cane was slightly infested with mosaic.

Diseases of corn bearing a decided resemblance to the one in question have been reported from other countries. Dr. H. L. Lyon states[4] that in the Hawaiian Islands a disease of corn which resembles sugar-cane mosaic is very serious. William H. Weston[5] describes a disease of corn in Guam which may be identical with the one under discussion. He mentions yellowing and dwarfing among the symptoms and states that the leaves exhibited mottling and striping.

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1 From Journal of Agricultural Research, 9:517-522, 1920.

2 Pathologist, Office of Sugar-Plant Investigations, Bureau of Plant Industry, United States Department of Agriculture.

3 Brandes, E. W., "The Mosaic Disease of Sugar Cane and Other Grasses," U. S. Dept. Agr. Bul. 829, 26 p., 5 fig., 1 col. pl. 1919.

4 In verbal communication, January, 1920.

5 Weston, W. H., "Report on the Plant Disease Situation in Guam," Guam Agr. Exp. Sta. Rpt. 1917, pp. 45-62. 1918.

Varietal Susceptibility

Just enough work has been done on varietal susceptibility to prove that all varieties of corn do not respond in the same way. The writer has never seen such excessive injury as that described for the unknown variety in Guam by Weston. In Louisiana the injury to corn of the White Creole variety, while marked in some individuals, was not excessive, excepting when the plants were infected early in the spring. The variety U. S. Select No. 182 is very susceptible to mosaic, but is not especially injured by it. Golden Bantam sweetcorn could not be infected in the greenhouse by methods which were successful with U. S. Select No. 182. Golden Bantam was planted unprotected in a greenhouse with hundreds of infected sugar-cane and sorghum plants. The corn aphis quickly migrated to the young corn plants from diseased sorghum in great numbers, but no cases appeared among the Golden Bantam seedlings. It seems probable that this variety is immune.

Importance

No figures are available on the amount of loss sustained on account of injury to corn. The writer is inclined to believe that in this country no great damage has been done thus far. Probably the disease was introduced on sugar cane within comparatively recent years, in which case it may become more important in the future. At present, however, our chief concern is with its relation to the sugar-cane crop. Corn is almost invariably used in the rotation on sugarcane land, so that no plantation is ever without corn in some of its fields. This means, of course, that the possibility for spread of the disease is greatly increased. Overwintering by the virus has been demonstrated only in the vegetative portions of the sugar-cane plant, but the existence of other graminaceous hosts certainly complicates the problem of control.

Symptoms

In corn as in sugar cane the most conspicuous symptom of mosaic is the streaked and irregularly mottled appearance of the leaves. In corn, however, the lower, older leaves have a greater tendency to resume their normal color, so that it is sometimes difficult to demonstrate the mosaic patterns in such leaves. In the youngest leaves, either the normal dark green or the pallid, affected tissue may predominate in a given specimen, but the latter condition is most frequently met with. In such cases the areas which remain normal are in the shape of broken or interrupted streaks or lines extending in the general direction of the long axis of the leaf (Pl. 95), and the contrast in color between these areas and the surrounding pallid areas is very decided. The streaks vary greatly in size, ranging from mere points to elongated "islands" of dark green 2 or 3 cm. or more long and several millimeters wide. The margins of such streaks may be straight or undulating. In most cases the mosaic pattern is more prominent at the base of the leaf, where it diverges from the leaf sheath. Where the normal dark green is predominant, the light green, affected tissue appears usually as a

very fine mottling or as irregular elongated streaks on the darker background. From the foregoing description it can be seen that the patterns vary considerably, and yet they have certain general characteristics which make it almost impossible to confuse this condition with any other affecting the leaves.

Infected plants are always lighter in color than healthy plants. When viewed from a distance such plants can be picked out with a fair degree of accuracy on this account. The top of the plant is especially pale, much more so than normal freshly unrolled young leaves. In some cases the color becomes decidedly yellow. In this connection it must be stated that the pallid color referred to heretofore as characteristic of the diseased areas is not a yellowish green but a lighter or more dilute tint of the normal green. In plants which become markedly yellow a decided stunting of the whole plant takes place. At no time has a case been observed to terminate fatally, but certain considerable injury results from the lack of functioning chloroplastids, and where a large percentage of the plants are affected the loss due to decreased size of ears is appreciable. When infection takes place early in the growing season, partial or complete sterility of the ears results. This serious feature of the disease was first noticed in Louisiana in 1920. In May, 1920, the writer tagged 20 diseased and 10 healthy plants in a field of White Creole corn. The diseased and healthy plants were equally vigorous to all appearances at that time and were in the same rows, alternate diseased and healthy plants in the same row being selected as far as it was practicable. When the crop was harvested in August, 17 of the diseased plants were found to be completely sterile, while 3 of them had set a few scattered kernels. The 10 healthy plants were normal, excepting for slight corn earworm injury, and produced large well-filled ears (Pl. 96).

During the course of experiments in the greenhouse several cases of apparent recovery have been observed. Plants which became infected and exhibited the typical symptoms resumed their normal color after several weeks. These plants were held under observation until the ears were mature, but there was no recurrence of the mosaic symptoms. This interesting behavior was also noted in stools of crabgrass (*Syntherisma sanguinalis*) and foxtail (*Chaetochloa lutescens*). There were no changes of growing conditions that could be correlated with these apparent recoveries. In this connection it may not be out of place to record that suckers from diseased stools of sugar cane and sorghum have been observed to come up with no sign of mosaic. These instances are by no means common, but several have been seen in both plants mentioned.

Insect Transmission of Corn Mosaic

The manner in which corn mosaic is transmitted to healthy plants and the relation of this disease to mosaic in other grasses was demonstrated by the following experiments:

Experiment 1.—On March 12, 1920, 12 corn plants of the variety U. S. Select No. 182 were placed in each of two insect-proof cages. All of the plants were from the same lot of seed furnished by the Office of Cereal Investigations.

The seed had been planted in one flat, and the seedlings were replanted in 5-inch pots on the date of removal to the cages. They were then 12 inches tall. About 12 individuals of *Aphis maydis* were carefully removed by means of a small camel's-hair brush from sorghum plants affected with mosaic to each corn seedling in one of the cages. The sorghum plants had been infected by aphids from mosaic sugar cane. Twelve aphids were transferred in the same way from healthy sorghum to each of the corn seedlings in the adjoining control cage. On March 28, 6 of the 12 corn seedlings in the first cage showed typical signs of mosaic in the two youngest leaves. On April 6, 8 of the plants, or 66⅔ per cent, were typical cases. The 12 control plants remained healthy up to the time of removal several weeks later.

Experiment 2.—On April 6, 1920, 20 corn seedlings, variety U. S. Select No. 182, in 5-inch pots were placed in each of two insect-proof cages in the greenhouse. Several specimens of *Aphis maydis* were transferred from infected corn plants to each corn seedling in the first cage. Aphids from healthy corn in another greenhouse were placed on each corn plant in the second control cage, which was used as a control. On May 4, 7 of the corn seedlings in the first cage were found to be infected. On May 28, 15 of the 20 plants were observed to be unmistakable cases. The aphids had increased enormously in both cages. Not a single case could be found in the control cage, nor had any appeared up to June 25, although the plants had been repotted twice and were approaching maturity.

These experiments demonstrate conclusively that provision is made for almost unlimited dispersal of the virus through the medium of the corn aphis. There is no reason for supposing that transmission in nature is limited to this insect or to this method. It is not yet known whether the virus can survive the winter in seed, but experiments are now under way that may throw some light on this phase of the problem. It has been proved that the virus of corn mosaic is identical with that of sugar-cane and sorghum mosaic, so that even if it is found not to be seed-borne, perpetuation of the disease in the perennial grasses would explain its appearance on corn in the spring.

Artificial transmission of the disease by means of inoculation with expressed cell sap of affected plants has not been attempted for corn. This method has proved successful in sugar cane, however,[1] and there is little doubt that the infectious material is contained in the cell sap of corn. Just what this infectious material is can not be stated definitely, but the evidence points strongly toward a living organism. No evidence incompatible with this view has been put forward for any mosaic disease, excepting the failure to demonstrate any visible organism.

Control

Control measures for this disease must be based fundamentally on the removal of sources of the inoculum. So far as is known the only sources of inoculum are the living host plants. Destruction of these plants, then, will effectively

[1] Brandes, E. W., "Artificial and Insect Transmission of Sugar-Cane Mosaic," in Jour. Agr. Research, V. 19, No. 2, pp. 131-138. 1920. Literature cited, p. 138.

eradicate the disease from any region. Practically, the destruction of all affected host plants presents almost unsurmountable obstacles. An immense amount of sugar cane is now infected in the River District of Louisiana and in southern Georgia. Destruction of large numbers of plants by roughing or plowing up is viewed with great concern by the planters, most of whom oppose any plan to control the disease by eradication. The substitution of immune varieties of corn as well as cane does not offer any immediate solution, since the most susceptible varieties happen to be the ones most esteemed. Elimination of this disease is dependent upon the education of the planter to an understanding of its seriousness. When this is accomplished public sentiment will permit of the passage of compulsory roguing and quarantine laws, which will be necessary before any hope can be entertained of eliminating the disease.

[L. O. K.]

Plate 95. Mosaic Disease of Corn: The first leaf at the left shows the typical interrupted streaks of normal green in a pallid green background. The next leaf shows a more irregular, mottled pattern. In these specimens the normal green was similar to "nickel green" and the pallid green was similar to "rejame green" in Ridgeway.[1] The two leaves at the right are from a healthy plant and are presented for comparison.

[1] Ridgeway, Robert, "Color Standards and Color Nomenclature," 43 p. 53 col. pl. Washington, D. C., 1912.

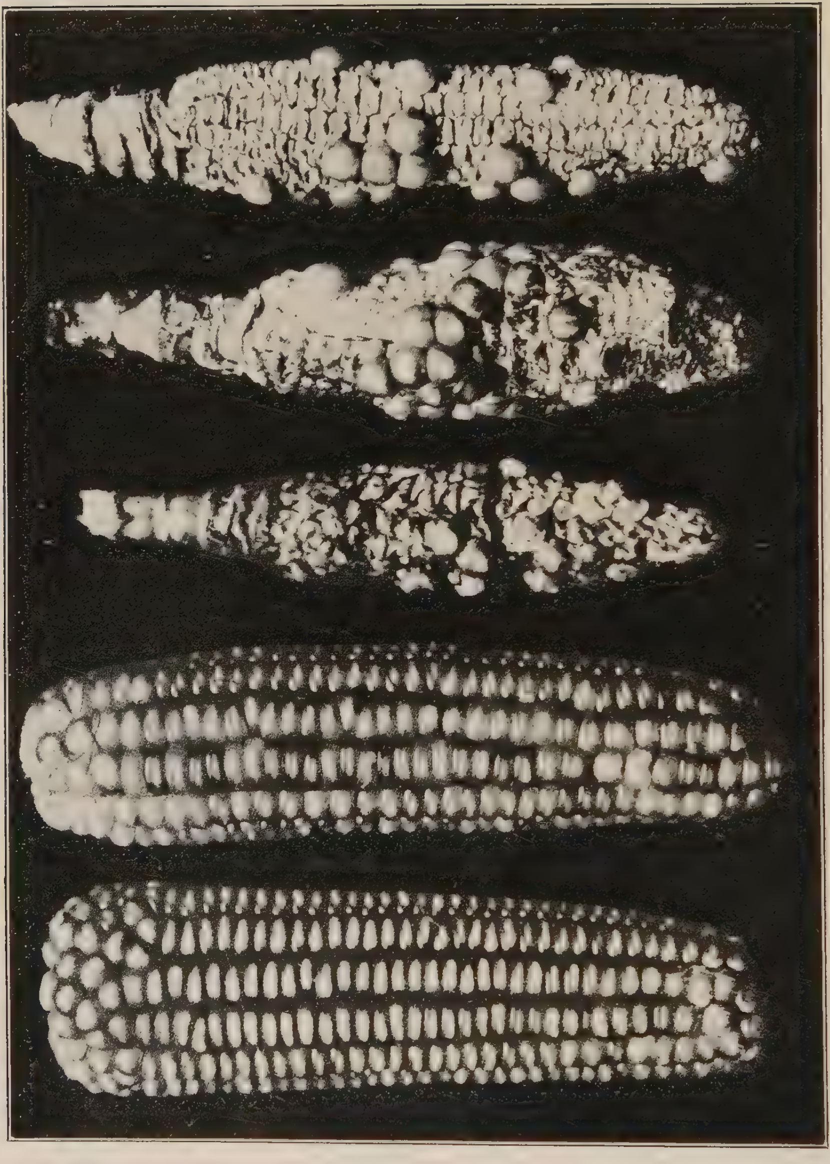

Plate 96. Mosaic Disease of Corn: Effect of early infection on the ear. White Creole variety.

The three ears at the top were produced by plants naturally infected in the field. In 17 out of 20 marked plants no kernels at all were developed.

The two lower ears are typical of all ears produced by healthy plants in the same row with the diseased plants.

Sugar Cane Diseases in Porto Rico.

The three following articles, treating of sugar cane diseases in Porto Rico, are reprinted on account of their general bearing on certain local problems which are receiving critical attention at the present time. The results of Mr. Matz's investigations on the cane root disease corroborate our findings insofar as the parasitic relation of a Pythium *to the root rot disease is concerned. We have not, however, yet found a vascular organism corresponding to the suspected* Plasmodiophora *discussed by Mr. Matz in the article entitled "A New Vascular Disease of Cane."*—C. W. C.

SUGAR CANE ROOT DISEASE.[1]

By F. S. Earle.

For several years past attention in Porto Rico has been so centered on the damage caused by the sugar cane Mosaic or Yellow Stripe disease that there is danger of overlooking the even more serious losses caused every year by the so-called root disease. This trouble is always with us. There is not a cane field in the Island that is not more or less affected by it. It is the cause of the dying out of the cane in so many fields that necessitates such frequent replantings. If it were not for root disease we would be today cutting twenty or thirty ratoon crops from each planting of cane as was done in the early days of the cane industry on this Island, and is still being done on virgin lands in eastern Cuba and in Santo Domingo. The expense of these frequent replantings is by no means the only loss caused by root disease. It is safe to say that one form or another of the troubles known under this collective name is causing a loss of tonnage on every acre of cane now growing in Porto Rico. Few cane planters who really understand these facts will question the statement that this is by far the most serious problem that confronts the cane growers not only in Porto Rico but on old lands in all parts of the sugar-cane-growing world. Unfortunately the question is very complex and obscure. There is probably no other plant disease of equal importance about which so little is really known and concerning which such erroneous ideas have long passed current in plant-disease literature. Some chance discoveries recently made in connection with studies of the cane mosaic have thrown new light on this most important subject and it seems opportune at this time to attempt a review of the entire problem.

Symptoms.

The symptoms of root disease are sufficiently well known to most cane

[1] Journ. Dept. Agr. Porto Rico, 4:3-27, 1920.

planters, yet they are not easy to accurately define. In the earlier stages they amount to little more than the slowing down of the normal growth of the cane. They are exactly the symptoms that would be expected when cane is planted on old worn-out lands without proper fertilizers. In other words, they are the preliminary symptoms of mal-nutrition, a lack of vigorous growth and a paling or slight yellowing of the leaves from the dark-green characteristic of cane in full vigor. These symptoms will be accentuated in dry weather, especially if this follows a period of excessive rains or in spots that have suffered from insufficient drainage. Bad drainage always intensifies the trouble from root disease. If drouth continues the leaves will begin to roll up during the middle of the day on the worse-affected spots. Later the lower leaves will die prematurely but will usually still hang to the stalk, not falling like normally matured leaves. The old leaf sheaths near the ground will often be found to be matted together and cemented to the stalk by a conspicuous white, mould-like fungus mycelium. Still later the tips and margins of the remaining living leaves will be seared and brown and the general color becomes quite yellow. When rains come this diseased cane may regain its color and continue to make some growth, but it never regains full vigor. As maturity of the crop approaches another phase of the trouble presents itself. The terminal bud on the more feeble stalk dies and this is followed by the rotting of the soft terminal tissues. This "top rot" is well known and is often incidentally referred to in cane-disease literature, but it has never been satisfactorily explained. Of course, a top rot, especially in young cane, when it is usually referred to as "dead heart," is often caused by injuries from the moth borer (Diatraea). A top rot of young overshaded suckers is also often caused by the fungus *Sclerotium Rolfsii,* which is everywhere present in cane fields. The top rot referred to above, however, comes from neither of these sources, but in the opinion of the author is the direct result and culmination of the symptoms that have so long been known under the collective name of "root disease." Soon after the dying of the top the black pustules of the fungus *Melanconium* appear on the stalk, usually beginning at the top of the stalk, following up the work of the top rot, but sometimes first appearing near borer injuries or on sun-scalded areas, and "rind disease" finishes the work of destruction by completely rotting the stalk unless harvesting quickly follows the appearance of top rot. The losses sometimes following from top rot and rind disease, which is now to be considered as the final manifestation of "root disease," are clearly shown by the notes (see page 260) on the variety experiment at Santa Rita, when, as early as December 10, before most of the mills had begun grinding, some of the more susceptible varieties were a total loss and where in the 90 plots of the standard Rayada the estimates showed an average of 29.4 per cent of top-rot stalks. Finally, after a severe case of root disease, the cane stubble fails to ratoon, or at best ratoons very poorly. Such stools must be dug out and replanted if a ratoon crop is expected. This replanting of ratoons is carefully attended to in Porto Rico, where it is part of the usual plantation routine. In Cuba it is frequently neglected, with the consequence that great vacant areas soon appear at the worst diseased spots in the field. These are locally known as

"sabanas," and they increase in area from year to year till the field is finally abandoned and plowed up.

The symptoms of root disease may then be summarized as follows:

1st. A slowing down of growth and lack of vigor, accompanied by a more or less pronounced yellowing of the leaves.

2nd. The rolling up of the leaves at mid-day during periods of drouth.

3rd. The premature dying of the lower leaves which remain hanging on the stalk and usually by the cementing of the leaf sheaths by a white fungus mycelium.

4th. A leaf burn causing the dying and browning of the tips and margins.

5th. Top rot, the dying of the terminal bud, followed by a soft stinking rot of the soft growing tissues.

6th. Rind disease, the appearance on the stalks of *Melanconium* and other fungi causing the rotting of the stalk.

7th. Failure to ratoon.

Historical.

During the first half of the last century the cane variety variously known as Caña Blanca, Bourbon or Otaheite, came to be grown very extensively in practically all of the tropical sugar-producing countries. It is a variety particularly well adapted to the rich porous soil of newly-cleared forest or so-called virgin lands, where it grows with great rapidity, giving a heavy tonnage of cane which yields a good percentage of sugar and which has unusually good milling qualities. Unfortunately, however, its root system is not adapted to the conditions found in old compacted soils. In one sugar-producing country after another this variety has given down, often with an apparent suddenness that has caused a serious crisis in the sugar industry, and it has been necessary to replace it by kinds better adapted to the compacted condition of old partially exhausted soils and more resistant to the complex troubles usually known under the name of Root Disease. Such a crisis occurred in the islands of Mauritius and Bourbon as early as 1846. In Porto Rico the outbreak in the Mayagüez district of the so-called epidemic of 1872 was clearly a manifestation of root disease. Similar crises have occurred in Jamaica and other of the British West Indies. In Java the problem was complicated by the presence of the Sereh disease and the Yellow Stripe or Mosaic, but the present custom of taking no ratoon crops but replanting the field annually has clearly largely come from the effect of root disease. In Cuba the abandonment of the Caña Blanca has been equally complete on all of the older cane lands, but as such a great area of virgin land was available for new plantings no sudden crisis resulted from a forced change of varieties. Fields of Caña Blanca (Otaheite) may still be found on the new lands of Eastern Cuba, but even here it is being rapidly replaced by the Crystalina. In Porto Rico this variety which was once so universally planted has practically disappeared except in certain loamy irrigated soils of unusually good texture on the south coast and in limited areas of the richer hill lands of the interior. Even here it does not ratoon well, but usually has to be replanted every year. The

entire question of varietal resistance to root disease is so important that it will be discussed under a separate heading.

Wakker in Java seems to have been the first investigator to assign a definite cause to sugar cane root disease (Arch. V. Java Suikerindus, 1895). He found a small gill-fungus or mushroom growing on the trash at the base of diseased stalks which he considered to be the cause of the trouble. He named and described this fungus as *Marasmius sacchari* n. sp. His work has been accepted and followed by most subsequent investigators, and to this day the terms root disease and Marasmius disease are used interchangeably in most publications on cane diseases.

During the years 1899-1902 Albert Howard was investigating sugar cane and other plant diseases for the Imperial Department of Agriculture of the West Indies with headquarters in Barbados. He seems to have been the first to identify our West Indian Root Disease as being identical with the trouble in Java. He found and identified *Marasmius sacchari* Wakker, and carried out a series of experiments that convinced him that it was the true cause of the trouble. In this he has been followed by Lewton-Brain, Bancroft, Tempany, Stockdale and other pathologists who have been connected with the British West Indian Department of Agriculture.

During the years 1904-1906 root disease was investigated in Cuba by Cook and Horne. They found an abundant white mycelium involving the bases of the old leaf sheaths, but during this period found no fruiting bodies of the *Marasmius.* (Estac. Agro. de Cuba Bull. 7, 13, 1907.) They did find, however, the fructifications of another Hymenomycetus fungus, *Peniophora* sp., which they suggested as a possible cause for the disease. This was not supported by experimental evidence.

In Circular 18 Horne refers to this fungus again as probably being *Hypochnus sacchari.* In the second report of the Cuban Station (Inf. Ann. Esta. Agr. de Cuba 2:81--, 1909, Horne again discusses root disease. He reports the finding of abundant fructifications of *Marasmius sacchari* Wakker in the fall of 1908 not only at the base of cane suffering from root disease, but also on Johnson grass, Para grass and Guinea grass. He inclines to attribute the root disease to this fungus rather than to the *Peniophora,* but again gives no experimental proofs.

In Hawaii in 1905 Lewton-Brain published as Bul. 2 of the Sugar Planters' Experiment Station a paper entitled "Preliminary Notes on Root Disease in Hawaii." At this time he had not found fruiting bodies of Marasmius, but he considered the disease as identical with the West Indian root disease with which he was familiar in Barbados. The following year Marasmius fruiting bodies were found in connection with the root disease. These were named *Marasmius Sacchari var. Hawaiiensis* by Cobb. (Sugar Station Bull. 5:214, 1906.) In this same publication, which is entitled "Fungus Maladies of the Sugar Cane," Cobb describes at great length a stink-horn fungus which he calls *Ithyphallus coralloides* n. sp. and to which he ascribes the principal role as cause of the root disease. The whole question was discussed and illustrated most elaborately, but without one word of proof to establish the causative relation of this fungus, which is one of the last that could reasonably be expected to be a parasite.

Cobb's work has not been confirmed by other investigators, so this profusely illustrated paper may be dismissed as one of the curiosities of pathological literature.

In 1908 R. H. Funton discussed root disease in Louisiana (Expt. Sta. Bull. 100). He ascribed it to a *Marasmius*, but to a different species, which was determined as *M. plicatilis* Wakker.

In Porto Rico this disease has been extensively studied by both J. R. Johnston and J. A. Stevenson during the time of their connection with the Insular Experiment Station. In their joint paper on Sugar Cane Fungi and Diseases of Porto Rico (Jour. Dept. Agri. Porto Rico 1-(4) 1917) they enumerate and describe *Marasmius sacchari* Wakker, *Himantia Stellifera* Johnston sp. Nov., *Odontia saccharicola* Burt, *Odontia Sacchari* Burt and some other Hymenomycetous fungi as occurring at the base of cane stalks and apparently in connection with root disease, but they say (p. 189), "The exact status of root disease with respect to the parasitism of *Marasmius, Himantia, Odontia* or possibly other forms is uncertain, and while it is generally held that *Marasmius* at least is a true parasite, really definite evidence is lacking. Studies under controlled conditions must be carried out working with pure cultures of the fungi which has not yet been possible."

Stevenson in his more recent papers has used the term "Deterioration" to cover part of the symptoms that have been above described and has attempted to separate them from what he calls "Root Disease." This he considers as being caused by parasites, but as quoted above he does not consider it as proven that either *Marasmius* or the other conspicuous Hymenomycetes connected with the disease are its true cause.

In the *Hawaiian Planters' Record* for July, 1919, Mr. H. L. Lyon has published a paper entitled "A Preliminary Report of the Root Rot Organism." In this paper he describes and figures an organism which he does not name but assigns to the *Chytridineae* which he considers "the primary cause of the Lahaina disease (of cane) and pineapple wilt throughout these Islands and perhaps in other tropical countries as well." The vegetative stage of this organism consists of small naked plasmodia either rounded or irregular and elongated, which occur two or more together in the same root cell. These plasmodia are believed to fuse and to then form either a sporangium or a resting spore, since these are uniformly found only one in each host cell. The sporangia soon give rise to motile zoospores. The resting spores are thick-walled globular bodies. They were kept under observation for several months, but it had been impossible to induce them to germinate. They occur in the soft tissues of the root often near the growing point. When the presence of this organism causes the death of a root it is soon completely destroyed by secondary organisms.

The above hasty review of the literature of Root Disease is in no sense intended as a complete bibliography, but it is believed that it covers all of the different views that have been published regarding this disease, or as perhaps it had better be called this complex of diseases. It should be added that white grubs (*Lachnosternum*) and other root-eating insects often produce somewhat similar symptoms, the results to the cane being much the same whether the roots

are killed by fungi or are eaten off by insects. A certain amount of such root insect injury is doubtless often included under the general name of root disease. Mealy bugs too (*Pseudococcus*) are very abundant in most cane fields and aid in creating that state of debility that accompanies the first stage of root disease.

The technical studies on certain organisms connected with root disease that are reported on another page of this publication by Mr. Matz represent a distinct advance in our knowledge of this most important complex of diseases. When Mr. Matz came to the Insular Station a little over a year ago the present writer took every occasion to impress on him the overshadowing importance of root disease as a sugar-cane problem and pointed out the entirely inadequate treatment of the question in plant-disease literature. He personally collected and brought to the laboratory much of the material on which these studies are based and has watched every step of the investigation with closest interest. He therefore feels competent to discuss the results and to express a decided opinion on the following points:

1st. *Marasmius* is at best a very feeble parasite. It may overrun new healthy roots or other organs without killing them. The same may be said of the so-called "stellate fungus" and of the other Hymenomycetes that form a conspicuous white mycelium on cane trash and at the base of cane stalks.

2nd. The killing of the roots which is so marked a feature in "root disease" is usually caused by various species of *Rhizoctonia* and sometimes by a species of *Pythium*. These are the well-known causes of the damping off of seedlings and cause heavy losses in tobacco and vegetable seed beds, but they have not before been connected with a disease of cane.[1] This seems most remarkable in view of the fact that some one of these species has been isolated from almost every diseased cane root from which cultures have been made and that in

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1 Since the above was written Hawaii Federal Station Press Bulletin 54 (issued December 9, 1919) has been received. It is by C. W. Carpenter and is entitled "Preliminary Report on Root Rot in Hawaii." In this interesting paper Mr. Carpenter attributes the root rot of cane, taro, bananas and rice and the wilt of pineapples in Hawaii all to the action of a species of Pythium which he considers as probably P. DeBaryanum. In discussing Lyon's paper he expresses the opinion that the resting spores found by the latter in cane and pineapple roots are in reality the oospores of this *Pythium*. Oospores have been produced abundantly in Mr. Matz's cultures here of *Pythium* from diseased cane roots. They certainly strikingly resemble the bodies figured by Lyon, but they are always accompanied by a conspicuous mycelium. Furthermore, they germinate readily. These facts make us doubtful whether or not Carpenter and Lyon are discussing two distinct organisms. Mr. Carpenter's paper, however, corroborates Mr. Matz's conclusion that *Pythium* is one of the active agents in killing cane roots.

A review of additional literature not accessible when the above note and paragraph was written shows that Pythium has long been known to attack cane roots. In discussing the Sereh disease in Java, Dr. M. Treub in 1885 (Med. Slands Plant, Buitenzorg 2:30-35, 1885) refers at some length to *Pythium* on the roots as a possible cause. In 1896 Dr. J. H. Wakker in a paper entitled De Schimmels in de Wortels van Het Suikerriet (Med. Proefs. Oost-Java (n. series) 21), gives a fine plate and a long discussion of *Pythium* as the cause of the killing of cane roots. The more conspicuous *Marasmius* seems, however, to have attracted his attention more strongly, as it has that of most subsequent investigators, and no subsequent mention of *Pythium* as a cane fungus has been found in the literature until that of Carpenter as mentioned above.

every case they have promptly killed every cane root on which pure cultures have been planted. Nothing could be more convincing than that these heretofore unsuspected species and not *Marasmius* and its allies are the true root-killing agents. We can only conclude that previous workers have done little in the way of making cultures from dying cane roots or they could have hardly failed to have detected these fungi which are so easily isolated and grown in artificial cultures.

This very satisfactorily clears up what may be considered as root disease proper, viz., the actual killing of the roots. The conditions under which this occurs and its relations to cultural practices will be discussed in another paragraph. The above organisms are all facultative parasites, and as such may be controlled at least to some extent by cultural methods.

3rd. The finding of a strict parasite within the vascular bundles of cane suffering from root disease was an entirely accidental and unexpected result from some anatomical studies of cane tissues made in connection with the investigation of the sugar-cane Mosaic (see Journ. Dept. of Agr. Porto Rico, Vol. III, 4, Oct., 1919). At first it was thought that this organism might have some connection with the mosaic disease since it was originally discovered in the tissues of an advanced case of mosaic. Later, however, it was found not once, but very many times and from widely different localities in cane that was suffering from root disease but that was absolutely free from mosaic. The evidence is conclusive that this organism is connected with the former disease but not with the latter.

Its life history has not been fully worked out. The vegetative stage consists of a yellow plasmodium which occupies the larger vessels of the vascular bundles, often completely filling them for considerable distances. Infected bundles may be easily detected with a hand lense, or even with the naked eye, in either cross or longitudinal cuts on account of their peculiar orange-yellow color. This is quite distinct from the reddening of the bundles that so often accompanies any mechanical injury. These plugged bundles are more abundant near the base of the cane, especially in the part which develops below ground, but they have also been found in the roots, and they can often be traced for long distances up into the cane, occasionally, in mature cane, almost to the terminal bud.

This plasma is multi-nucleate. After a time each nucleus surrounds itself with a rounded mass of the cytoplasm and begins to divide first into two, then into four, and finally into a mass of dense granules. At the same time a cell wall is being formed and the result is a globose, thick-walled resting spore. The cell wall is smooth and hyaline, but the content is so densely granular that the spore is dark and opaque. They are produced in great numbers and remain imbedded in the cytoplasm, which finally becomes somewhat hardened and gum-like. So far these spores have resisted all attempts to germinate them. The remainder of the life-history can therefore only be conjectured. It seems most probable that when these infected canes and cane stubbles rot in the soil these resting spores are liberated and in their own good time germinate probably by the formation of motile zoospores. These probably find their way into new cane roots and thus start the infection of other canes. It is evident also that when infected canes are cut up and used as seed for new plantings that the

disease could be propagated in the new field by the continued growth of the original plasma.

If the above hypothesis is correct and these resting spores do break up into motile zoospores the organism would have to be classed among the *Myxomycetes* or Slime moulds. The only recognized genus to which it could be referred would be *Plasmodiophora*. It differs from the known species of this genus in the much larger size of the spores and in the fact that it causes no enlargement or distortion of the cells of the host. It seems best to withhold a final opinion as to its name and systematic position until its life history has been more fully determined.

The resting spores of this organism are so very similar to those figured and described by Lyon for the supposed Chytridiaceous fungus discovered by him as a cause of root disease in the Hawaiian Islands that it was at first assumed that we had found the same organism. This, however, can hardly be the case. We have found nothing resembling the sporangia and definitely formed phasmodia which he figures. The resting spores of his organism occur singly in the parenchyma cells of the young roots and the epispore is irregularly thickened. Our organism is in the vascular bundles, not the parenchyma. The plasmodium is indefinitely continuous, often for a distance of many centimeters. The numerous resting spores have a smooth cell wall of equal thickness throughout. It seems clear that this organism belongs in the Slime moulds and not in the *Chytridiaceae*. It is, however, remarkable that two such similar but distinct organisms are causing serious damage to sugar cane in different parts of the world and that both had so long escaped detection.[1]

It is not possible as yet to express a fixed opinion as to the damage being done by this vascular bundle parasite, nor as to its exact role in the complex we are considering under the name of "root disease." It is not probable that it is an active agent in the actual killing of roots. In fact, it is quite certain that this is not the case. The actual root killers are facultative parasites, and as such their action is largely inhibited when the cane is in full vigor. The bundles fungus is doubtless one of the many contributing causes to lack of vigor and thus may be indirectly responsible for loss of roots. Whether its action is merely mechanical, simply resulting in the plugging of the bundles it occupies, or whether it may secrete injurious substances we do not know. If the former, an occasional plugged bundle will cause little or no harm, but if many of the bundles are invaded the result would inevitably be the rolling up and withering of the leaves and finally the death of the terminal bud. It seems probable, therefore, that this bundle fungus is correlated with the baffling condition known as "top rot" rather than with "root rot" proper.

Whatever the damage it may be doing it is widely scattered in Porto Rico, having been found in every cane-growing district where a search has been made for it. It is interesting to note that the old Caña Blanca (Otaheite or Lahaina) is particularly susceptible to it. It was found to be very abundant in the few stalks of this kind that have survived in the experimental plots at the Mayagüez Station where it had been interplanted among the other kinds as a check and

[1] See note on page 254.

where it practically all failed to ratoon at the end of the first year. This particular field, by the way, is said to be the one where the famous epidemic of 1872 first made its appearance. This may be only a coincidence, but it at least suggests this as one of the factors in that outbreak.

The habit of growth of this fungus makes it certain that it has been widely transported in seed cane. It therefore probably has a wide distribution in all cane-growing countries. It should certainly be carefully searched for by all investigators. Its presence indicates the great unwisdom of taking seed cane from old, neglected fields where it is quite certain to be more abundant than in new plantings. It also probably explains the better results usually obtained from planting "top seed," since it is comparatively rare for this organism to reach the top joints of the cane. Where the entire cane is used for planting the butt cut should certainly be rejected, since this is much more likely to be infected.

4th. The above discussion throws light on the much-discussed problem of "top rot."[1] It seems entirely probable that this bundle inhabiting, *Plasmodiophora*-like organism is the original cause of "top rot," aided, of course, by the root-killing fungi and the other factors of "root disease" that unite to lower the vitality of the cane. The writer is well aware that no positive proof has been given as to the causal agency of the bundle fungus in producing "top rot." He only wishes to point out the strong probability that this is the fact.

In cases of "top rot" the withering leaves of the terminal bud spindle soon show numerous, scattered, minute black spots which under the microscope prove to be the fruiting bodies of some fungus. As noted by Stevenson in his discussion of "wither tip" (Jour. Dept. Agr. Porto Rico, 1:207), this usually is found to be either *Sphaerella sacchari* Speg. or *Periconia sacchari* Johnston.

At about the time that these fungus specks become visible a stinking bacterial rot occurs in the soft tissue about the growing point. This rot only involves the soft tissues. Sometimes the disease is checked at this point, the rotted top falling away while the joints below remain sound, the lateral buds soon pushing into new shoots. More often, however, the black pustules of "rind disease" appear on the joints below the rotten tip and this soon completes the destruction of the stalk.

Clearly these bacteria and fungi so uniformly associated with "top rot" are saprophytes and agents of decay, but it is very probable that they are also facultative parasites and are able to attack cane tops that have been weakened by other causes without waiting for death to occur. This point needs further study. Whether the fungi or the bacteria or both are real killing agents has not been determined. In any event it seems certain that they cannot attack cane that is in full vigor and health.

Many references occur in the literature to a supposed bacterial top rot of cane, but no proof exists that there is a specific disease of this nature apart from the fact that bacteria are always present in the soft, rotting tissue.[2] The whole

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[1] Since the above was written, the Gumming disease or Sugar Cane Gumosis has been found in Porto Rico. (See J. Matz, Insular Station Circ. 20, 1920.) This also causes a top rot, but such cases can be distinguished by the flow of gum from cut surfaces of the stalks.

[2] Mr. Noel Deerr has informed the writer that a contagious bacterial top rot exists in Demerara, but his studies regarding it have not been published.

subject needs much careful investigation. The above discussion is intended to be suggestive rather than final.

5th. In the preceding paragraph the statement is made that "rind disease" usually sets in to complete the work of destruction caused by "top rot," the predisposing causes for this last condition being here held to be "root rot" and the presence of the bundle inhabiting *Plasmodiophora*-like organism. The "rind disease" here referred to is assumed to be caused by *Melanconium sacchari* Mass. The discussion of this fungus in plant-disease literature has been involved with many needless and really inexcusable errors. It seems clear that this fungus has nothing to do with either *Trichosphaeria, Thielaviopsis, Diplodia* or *Colletotrichum,* although eminent mycologists have frequently expressed a contrary opinion. This is a very common saprophyte, growing everywhere on dead cane trash. It is not an active parasite, but can attack enfeebled cane tissue before it is quite dead. It often follows borer injuries, but in these cases seldom is able to pass the nodes, being confined to the one injured joint. Where canes have been so weakened by "root disease" that they have fallen a victim to "top rot" the vitality is so lowered that the *Melanconium* is usually able to quickly invade and destroy the entire cane.

Varieties differ greatly in their power of resisting "rind disease," the Otaheite or Caña Blanca being particularly susceptible. This question will be further discussed in a subsequent paragraph.

To what extent the "red rot" caused by *Colletotrichum falcatum* Went. has been confused with "rind disease" it is not easy to determine, especially since they often occur together, in which case this fungus is likely to be overlooked, being obscured by the more conspicuous *Melanconium.* Apparently, *Colletotrichum* is not as injurious here as in many other cane-growing countries. It is, however, known to occur, and Stevenson reports the presence of three other unnamed forms of this genus as occurring on sugar cane in Porto Rico. Their distribution and economic importance should be given careful study.

6th. *Failure to ratoon.* Cane suffering from the advanced stages of "root disease" (including "top rot" and "rind disease") seldom ratoons well and in many cases fails entirely, thus causing the necessity for the early abandonment of the planting. This represents an even greater financial loss than the yearly shortage in tonnage. It may be considered as the final culmination of this series of disasters. It completes the picture of the complex of trouble as we now understand them that are grouped under the comprehensive name of "Sugar Cane Root Disease."

The Resistance of Cane Varieties to Root Disease.

Ever since root disease was first recognized it has been noted that different varieties were very differently affected by it, some being very susceptible while others were comparatively resistant. The old favorite Otaheite, Caña Blanca, Bourbon or Lahaina as it has been variously called, has always suffered more severely than any other kind in general cultivation. It seems to be particularly

susceptible to all phases of this complex of maladies. Its root system is delicate, and while well adapted to rich porous lands that are well supplied with humus, it quickly succumbs to the attacks of *Rhizoctonia, Pythium* and other root-killing fungi when the soil becomes old and compacted. It was never a strong ratooner and on unfavorable soils it often completely fails to ratoon even after the first cutting. In addition it proves to be a favored host for the vascular bundle fungus that has been above described, and the stalks are particularly susceptible to the *Colletotrichum* red rot and to the *Melanconium* rind disease. One or another of these troubles or a combination of them has caused its failure and abandonment in practically all cane-growing countries. The opinion has been widely expressed that this variety was degenerating. The facts, however, do not support this idea. Where all conditions are favorable it grows with its old-time vigor. It is simply a susceptible variety only adapted to a narrow range of conditions. It is the old, long-cultivated soils that have deteriorated and not the Otaheite cane.

It was the failure, often the sudden and disastrous failure, of this old favorite that first forced serious attention on other kinds and that has led in so many countries to the extensive production of new seedling varieties. Many of these new kinds have come to be extensively planted. In fact, the sugar industry of many regions is now based almost entirely on some of these new kinds. Their success has been almost entirely due to their resistance to root disease. It is a remarkable fact that among the multitude of new kinds produced and tested so few have surpassed or even equaled the old standard varieties in sucrose content and purity. New kinds are everywhere pushing out the old standard kinds, Otaheite, Crystalina, Rayada and Morada (purple), not because they are richer, better milling canes, but because they are more resistant to root disease and so give better tonnage for a longer series of years.

Much attention has been given to this subject in the British West Indies, and the reports from the different agricultural stations there are filled with notes on the resistance or susceptibility to the root disease of different varieties in different localities and different seasons. In the publications of the Porto Rico Stations casual mention can be found regarding the resistance of various kinds, but no comprehensive study of the question seems to have been made under our local conditions. A cooperative planting of 171 varieties made at Santa Rita, Guánica, in the irrigated district on the south side of the Island, for the purpose of testing their resistance or susceptibility to the Sugar Cane Mosaic, has been reported on in Bulletin 19 of the Insular Station. At the time of the last inspection reported in this bulletin, August 10, 1919, it was evident that some kinds were not doing as well as others aside from the effects of the mosaic infection.

It was suspected then that root disease was also at work, but as yet it was only in the preliminary stages, no signs of "top rot" or "rind disease" having appeared. Subsequent visits showed that the combined effect of the root disease and the mosaic were going to result in heavy losses from "top rot." It is not considered that the mosaic was in any sense a primary cause of this top rot. Its presence was simply one more factor in lowering vitality of the cane. Some

white grubs (*Lachnosterna*) were also present and helped to secure the total injury which ended in disaster for most of the kinds in these plots.

Rhizoctonia had been isolated from cane roots from this field early in the season and it was found that many of the canes were infected by the vascular bundle parasite. On December 10, 1919, about the time when Central Guánica is usually actively grinding the *gran cultura* plantings, a final inspection was made and the per cent of "top-rot" stalks in each row was estimated. It will be remembered that every third row in these plots was planted with Rayada seed infected with Mosaic in order to insure the equal exposure of the other kinds to that disease. There were 90 of these Rayada plots. The per cent of "top rot" was estimated in each of these. In 8 of them it was placed as low as 5 per cent. One was a complete loss, 100 per cent. The average of the estimated loss on the 90 plots was 29.4 per cent, so that figure is given in the following table. Twenty-six kinds had been cut for seed and had ratooned, so notes could only be taken on the condition of the ratoons. It is to be presumed that most of these kinds would have shown good resistance to the root disease had they been standing. Most of the top-rotted canes had developed rind disease and were fast becoming a total loss. The average condition of the field was deplorable, though it was planted on very fine land and had had the best of irrigation and cultivation.

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In discussing the above table[1] it must be borne in mind that practically all of this cane, excepting only the Kavangire, was heavily infected with Mosaic, which by lowering its vitality had greatly contributed to this disastrous result. It is considered, however, that this has only accentuated the effects of the root disease and has brought out with unusual clearness the resistance or susceptibility of these different kinds. The 26 kinds cut for seed in September were those considered most promising by the Agricultural Staff of Guánica. Had they remained standing they would doubtless all appear in the resistant lists. It is known from two seasons' observations at the Mayagüez Experiment Station that Java 36 and Java 234 are almost equally as resistant to root disease as the Kavangire. These three clearly make a class apart in their almost complete immunity to root disease and in their great ratooning power. It will be noted that the Kavangire is of straight North Indian blood, while the other two are hybrids with another North Indian cane, the Chunnee, as staminate parent. The so-called Egyptian cane (see Bulletin 19, p. 15) is probably Java 105 P.O.J., and if so is another of this set of hybrids. It promises to be equally resistant with the others but unfortunately it was not included in this experiment: we therefore have—

List 1.—*Varieties practically immune to root disease*:

Kavangire	Java 105 P. O. J. "Egyptian"
Java 36 P. O. J.	Java 234 P. O. J.

Of the remaining broad-leaved canes there are only four which showed no cases of top rot.

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1 A five-page table of detailed statistics not reprinted.

List 2.—*Highly resistant varieties, showing no top rot*:

B. 4596	G. C. 127
F. C. 214	G. C. 1539

List 3.—*Resistant varieties, showing general good conditions and only 2 per cent to 5 per cent of the top rot*:

B. 3578	G. C. 1254
B. 6450	G. C. 1486
F. C. 79	G. C. 1491
F. C. 193	G. C. 1522
F. C. 312	Java 228 P. O. J.
Fortuna Seedling	P. R. 292
G. C. 888	Sealey Seedling

The kinds cut for seed and which would probably have fallen in either 2 or 3 follow, as—

List 4.—*Varieties cut for seed, probably resistant*:

B-109	F. C. 277 **
B-3859	F. C. 322 **
Cavengerie	G. C. 606
D-435	G. C. 701 *
F. C. 95	G. C. 1313 *
F. C. 104	G. C. 1486 **
F. C. 133 **	G. C. 1504
F. C. 178	G. C. 1513 *
F. C. 199 **	G. C. 1518 **
F. C. 202	G. C. 1521
F. C. 204	G. C. 1545 *
F. C. 239	P. R. 260

Those marked with an "*" in the above list show a complete stand of ratoons, those with "**" have a complete stand and show superior vigor.

These lists include the only kinds that would have made a satisfactory commercial crop under the trying conditions of this experiment. The others grade all the way from a 15 per cent or 20 per cent reduction in crop to a complete loss. But for its extreme susceptibility to Mosaic disease Yellow Caledonia would assuredly have been found in one of these lists, since it has very considerable resistance to root disease. This table should have a great practical interest for every cane grower in Porto Rico, since it illustrates so forcibly the supreme importance of selecting the proper variety for planting in order to avoid very serious possible losses. It is seldom that circumstances combine to produce such striking results as were given by this experiment, but, on the other hand, there can be no question but that root disease is exacting a heavy toll in practically every cane field in the Island.

One of the most impressive lessons from this experiment is the outstanding superiority in resistance of the canes of North Indian parentage. Kobus in Java seems to be the only cane breeder who has realized and taken advantage of this most important fact. The continued indiscriminate breeding of new seedlings of the ordinary broad-leaved tropical type of canes does not seem to be leading to any advantage. Crossing a vigorous North Indian cane like Kavangire on the Crystalina, which represents the best of the rich-juiced, broad-leaved tropical canes, should lead to much more favorable results. Such crosses could be easily made by simply planting the two kinds in adjoining rows, since the Crystalina is

usually sterile to its own pollen. The present writer is only temporarily in Porto Rico. It is unlikely that he will ever have the opportunity to undertake cane breeding, but he strongly urges this cross on the attention of those who do continue in this work.

Remedial Measures Against Root Disease.

It is clear from the discussion under the last heading that the planting of resistant varieties is likely to prove the most effective remedial measure. It is also clear that the varieties descended from the slender, narrow-leaved North Indian canes show greater resistance to this complex of troubles than the stouter, sweeter, broad-leaved tropical kinds, though many of these last show very satisfactory resistance.

Making a complete change in variety is often difficult and it may be costly. It always takes considerable time. It must be admitted, too, that none of the resistant kinds so far tested is really equal to Crystalina and Rayada as desirable milling canes. It is of great practical importance, therefore, to consider what other remedial measures are possible and how satisfactory they have proven in actual practice.

It must be remembered that so far as we know all of the organisms that cause injuries in connection with this disease, with the one exception of the vascular bundle fungus, are facultative parasites. That is, they cannot attack tissues that are in vigorous growth, but only those that have become weakened from some cause or that have reached such a state of over maturity or senility that the vital processes are lowered. All of the root killers and all of the organisms found in the dead tops and in rind disease and red rot belong in this category. It is a fact of general knowledge that diseases caused by facultative parasites are as a rule best controlled by improved cultural methods. Cane-root disease is no exception. The more abundant use of properly balanced fertilizers; careful attention to drainage where needed, as well as the avoidance of unnecessary ditching; most important of all in Porto Rico, sufficient cultivation with implements to keep the soil open and porous and to prevent crusting; and the use of irrigation when soil or climate conditions demand it will go far to prevent the enormous losses now caused by this complex of diseases. On the contrary, the factors that contribute most largely to these losses are lack of fertility, lack of suitable drainage, hard, compacted, unworked soils, severe drouths, and injuries from insects or other diseases such as white grub, mealy bug or Mosaic. The author's experience in Porto Rico is limited, but he has observed innumerable instances in Cuba on old lands so exhausted that cane plantings run out after two or three light cuttings, where a reasonable annual application of fertilizer and good cultivation has not only resulted in considerably increased crops at the first cuttings, but has prolonged the life of the fields from two or three to eight or ten years. He has published in Circular 19 (Oct., 1905) of the Estación Agronómica de Cuba a photograph showing on the one side a vigorous field of ratoons going to their fourth cutting and on the other a grass field with one lone remaining stalk of cane. Both lots were planted at the same time. The one only showing grass was not fertilized, the other received 500 pounds per acre of a complete

chemical fertilizer when planted, but it had not been fertilized since, the residual effect of the one application still keeping the cane in comparatively good health and vigor, while the unfertilized cane had entirely disappeared. This was undoubtedly an unusual case, but it clearly illustrates the point under discussion, which is that a large percentage of the annual losses from root disease are easily preventable by following the simple agricultural practices mentioned in Circular 17 of this Station.

Unfortunately, the finding of a true parasite, the vascular bundle fungus, shows that not all of the losses can be prevented in this simple manner. Our studies so far do not indicate how serious a factor this may prove to be in the general complex, but it is entirely unlikely that it can be controlled by cultural methods. In the variety experiment at Santa Rita, the results of which have been already discussed, this organism was frequently found. The disaster which overtook that field notwithstanding fairly good cultural conditions seemed to depend on the complication with the severe infection of Mosaic disease rather than on the presence of this organism. The Mosaic disease by its influence in reducing vitality and inducing premature maturity is a factor exactly fitted to promote injury from root disease.

Aside from the selection of resistant varieties and the use of reasonably good cultural methods, one other point requires attention, and that is proper selection and handling of seed cane. The bundle fungus is undoubtedly transported and planted in the seed. There is less danger of this where top seed is planted and less danger when young plant cane is used than with old ratoons. In planting the entire cane for seed as in *gran cultura* the butt-cut should be rejected, as this is more likely to carry the bundle fungus and besides the bottom leaf sheaths are likely to be matted by the mycelium of *Marasmius* and other undesirable fungi. The seed cane, too, should be inspected and the butts should be cut off in the field where cut. The common practice of hauling the cane to the side of the new field and doing this work there is objectionable, since it leaves the infected butts and discarded canes on the border of the new field with every chance for infecting it.

Dipping seed cane in Bordeaux mixture will have little or no effect in preventing root disease. This treatment serves to protect the seed piece from the entrance of the pineapple-rot fungus (*Thielaviopsis*) or other rot-producing organisms. It can have no effect on the bundle fungus and will have little or no effect in preventing root killing by *Rhizoctonia, Pythium* or other facultative parasites.

Summary.

1st. Root disease as here understood is a complex including phases often known as Root Rot, Wither Tip, Top Rot and Rind Disease. These phenomena are caused by a number of facultative parasites, none of which attacks actively growing vigorous tissues. There is also a heretofore unknown true parasite inhabiting the vascular bundles. *Rhizoctonia* and *Pythium* are the usual root-killing agents rather than *Marasmius* and *Himantia*.

2nd. Cane varieties differ greatly in their resistance or susceptibility to Root Disease. The Otaheite or Caña Blanca is very susceptible. North Indian

canes like Kavangire and those with part North Indian parentage are very resistant or practically immune.

3rd. Remedial or preventive measures include—

A. The planting of resistant varieties.

B. Better cultural methods to overcome facultative parasites.

C. Proper seed selection and handling.

INVESTIGATIONS OF ROOT DISEASE OF SUGAR CANE.[1]

By J. Matz.

The root-disease problem of sugar cane has engaged the attention of many workers in the past, including the work of A. Howard on "Some Diseases of the Sugar Cane in the West Indies," published in 1903 in the Annals of Botany V. 17, pp. 373-412, in which the author gives an account of his experiments to establish a relation between *Marasmius sacchari* Wakker, and the root disease of cane in Barbados. From those experiments it appears that *Marasmius* is capable of causing damage to the sugar cane during certain unfavorable seasons. Under favorable conditions for the growth of the sugar cane plant the presence of the fungus on the plant did not seem to have a deleterious effect. The question arises if unfavorable seasons and unfavorable conditions in the field alone are not sufficient to produce an effect that might be similar to that which may result from a fungus attack on the roots of the plant. The fungus *Marasmius sacchari* is very common in a large part of the cane fields of Porto Rico and it has generally been taken to be the cause of root disease here. Johnston and Stevenson while describing root disease of cane in the Journal of the Department of Agriculture of Porto Rico, Vol. 1, No. 4, 1917, express doubt as to "the exact status of root disease with respect to the parasitism of *Marasmius, Himantia, Odontia,* or possibly other forms, * * * while it is generally held that *Marasmius* at least is a true parasite, really definitive evidence is lacking." During the past year an attempt was made to determine, if possible, the exact nature of root disease of cane, and the facts thus far learned are of sufficient interest to warrant their publication.

What Is Root Disease of Cane?

By root disease of any plant it is usually understood to mean decay of roots which result in either the rotting of the basal part of the plant or in a mere stunting and subsequent withering of the whole plant. In either case the symptoms should be clear enough as not to confuse it with other diseases. In cane there are many plants which could easily be taken as affected with root disease that may not be suffering from root disease at all. Borers of various kinds,

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1 Journ. Dept. Agr. Porto Rico, 4:28-40, 1920.

drouth, lack of cultivation, gum disease, top rot, and lack of drainage produce effects that may be taken for root disease. The cane plant as a whole has such a structure that injuries to the lower portion, whether caused by mechanical agents such as boring insects or by the physical condition of soil, or whether by fungi and bacteria which either clog up the conducting channels or fibers, thus starving the plant or simply decompose the roots through parasitism, the effects on the plant as a whole in all cases would be drying of leaves from the tips, top rot, stunting and shortening of the joints and a multiplicity of short sprouts. Therefore to distinguish root disease proper from other troubles of the cane which arise in the root region the term root disease is restricted here to mean a decomposition of roots taking place on account of the invasion of fungi. The symptoms of root disease therefore are primarily a decomposition or lack of healthy roots, dry leaves and stunted appearance of the cane. Top rot may also result indirectly on account of lack of sufficient roots to take up and conduct necessary water and food to the plant. The binding of the lower leaf sheaths has been generally taken for a symptom of root disease; that is, when *Marasmius sacchari* was taken as the parasitic cause of the disease. That symptom is not necessarily an accompaniment when another fungus is concerned with the decay of roots. Cane ratoons which exhibit all the effects of root disease, being stunted and having the lower portions of the stalks covered with adhering dry leaf sheaths and yet binding was not observed and the yellowish white mycelium of *Marasmius* was not noticed in between them. It is, however, reasonable to assume that the same ratoons had they grown in low and moist locations and if *Marasmius* had been present in that soil that binding would have taken place, as the fungus thrives well on dead cane leaves and stalks. It is quite possible that under unfavorable conditions of growth the cane plant may fall a prey to an organism which is not parasitic enough to be able to attack the cane had it grown under conditions conducive to strength and vigor. Such cases no doubt exist. But the semi-parasitic organisms do not add much more damage to the amount which is already caused by the unfavorable conditions, which may be poor drainage, lack of water and no cultivation or undesirable varieties planted on unsuitable soil lacking in plant food elements. The important factor in true root disease should be an organism which is capable of attacking essential roots and destroying them. With this point in view a search was made to find and isolate microorganisms from the interior of young but partially affected roots of cane. This effort was rewarded by finding *Rhizoctonia,* a root-destroying organism in the tissues of young roots, on seven different occasions, and *Pythium* sp. on two occasions. At the same time *Rhizoctonia* species were isolated from a large variety of plants other than cane, proving that this form genus is widely distributed in soils of Porto Rico.

The Isolations of Fungi from Cane Roots.

The first isolation trial was made in December, 1918, immediately after the writer had become connected with the Insular Experiment Station, from cane at the Santa Rita estate near Yauco. The cane plants were only a few months old from a *gran cultura* planting. The leaves did not show any abnormal appear-

ances at that stage, except yellow-stripe disease in some plants. On pulling up some plants, both yellow-striped and healthy, it was observed that the roots of some, though numerous, were mostly brown and partly decayed. Although the brown coloration is natural with older roots, the young and fleshy rootlets, however, were stained an unnatural red and the root cortex was dissolved and decomposed in part. Two plants were brought to the laboratory, and the younger and red-brown rootlets were cut off washed in running water, and with a flamed scalpel bits of the reddish and soft tissue were planted in corn meal agar plates. In about two days three fungi were observed in the plates. One was *Rhizoctonia* with its characteristic even mycelium and anastomosing side branches, another was a *Pythium,* latterly determined as such by its fructifications, and several colonies of *Trichoderma.* These three fungi were transferred to several tubes containing sterilized green bean pods. The *Rhizoctonia* transfers began to form yellowish sclerotia in about four days. At first these sclerotia were composed of loose but short and stout hyaline hyphae, later the masses became more compact and took on a deeper color. In about 3 weeks the mycelium in the tube became buff brown, and the sclerotia became darker and have attained a size of 1 to 3 millimeters. They are rounded and covered with a lighter growth of short hyphae. The culture presents all the general characters of the well-known *Rhizoctonia solani,* of which the writer has a culture which was isolated in Florida and compared with a culture of the same from Dr. B. M. Duggar of the Missouri Botanical Garden. Whether this cane *Rhizoctonia* is identical with or is a different strain from *R. solani* is reserved for another paper to be published in the future.

Inoculation Experiment.

Before searching any further for more fungi on cane roots an inoculation experiment was made to test the relation of the above-named three fungi to cane root decay. Rayada cane seed, each consisting of at least one entire internode and two nodes, were cut with a sharp knife about one-half inch above and below their respective nodes. These pieces were washed for 15 minutes in a 1 : 1000 solution bichloride of mercury, rinsed in running water and planted in steam-sterilized soil in six-inch pots. Three seed pieces were inoculated with the above *Rhizoctonia,* three with *Pythium,* and three with *Trichoderma.* This was done by placing a bean pod culture of one of the organisms on the seed piece and covering it all with about one inch of soil. The pots were watered and kept covered with paper for three days from inoculation. On the fourth day the top layers of soil were removed and the young roots, some of which had attained one inch in length, were examined. It was found that where *Rhizoctonia* and *Pythium* were used some of the young roots were red and soft. Small pieces of the latter were examined with the aid of the microscope and it could plainly be seen that the two fungi had entered and grown into the interior of the roots, causing a decomposition of the cells of the fleshy parts of the root. The characteristic *Rhizoctonia* mycelium, with its almost perpendicular branching and distinct walls, could be seen to ramify in and between the cells of the roots in the parts where that fungus was used as the inoculum, and the stout, uneven and

hyaline, non-septate mycelium of *Pythium* was observed to have grown around and between many root cells in the pots where this fungus was used. The fungus *Trichoderma* did not produce any visible change in the roots of the cane.

Having that much success with this first trial, another experiment was made, using the three above-named fungi and in addition pure cultures of *Marasmius sacchari* and *Odontia saccharicola*. Again *Rhizoctonia* and *Pythium* gave positive results, while *Trichoderma, Marasmium,* and *Odontia* did not affect the young roots. In this experiment six seeds were inoculated with *Rhizoctonia,* six with *Pythium,* three with *Marasmius,* three with *Odontia,* three with *Trichoderma,* and three were left as checks. Two strains of *Marasmius* were used; one was from a culture growing in pure state on sterilized cane leaves in flasks, the other was isolated by the writer from spores of hymeniums collected in a cane field at Río Piedras. The two strains were similar in all appearances, the first one probably having come from mycelium commonly found on leaf sheaths and basal parts of cane stalks. The method employed to obtain spore cultures from *Marasmius* and *Odontia* was by making a spore print on sterilized corn-meal agar. A drop of agar was placed on the inside of a Petri dish cover and a portion of the hymenium was stuck onto the agar. Then the top was placed over a corn-meal agar poured plate permitting the spores to drop on the surface of the agar in the bottom dish. With fresh hymeniums a spore print on sterilized agar was thus obtained in 24 hours. Single spores could then be transferred from the edge of the print where they are not too thickly sown. Both fungi were grown on sterilized green bean pods. The growth of *Marasmius* in pure cultures, from single spores, was producing white strands similar in appearance to the fungus usually found in connection with binding of the lower leaf sheaths. Other cultures from the white mycelium, usually taken to be *Marasmius,* were also made, and there was such an agreement of characters between these and the cultures from spores that the writer is inclined to the general belief that the common leaf-binding fungus in Porto Rico is no other than *Marasmius sacchari.* Further proof of the identity of the two forms was had by the fact that a culture of mycelium from matted leaf sheaths developed the spore-bearing stage of *Marasmius sacchari* when placed in soil in pots in which cane was growing. The cultures of *Odontia* spores were rather slow growing, producing a short, grayish and thin growth of mycelium on bean pods, after a while becoming water-soaked and giving to the bean pod itself an oily or more or less transparent aspect. There were no formations of mycelial strands or threads in these cultures. And the writer could not find any similarity of character between these pure cultures and the thread mycelia commonly encountered on cane soils in the field.

When the plants inoculated with *Rhizoctonia, Pythium, Trichoderma, Marasmius,* and *Odontia,* in the experiment mentioned above, were examined it was noticed that in the *Marasmius* pots, although the white threads of the fungus had penetrated through the upper three or four inches of soil, the growing roots of the cane seed were not affected in any unusual way. Mycelium was observed on some roots, but no rotting took place. However, after three months from inoculation there could not be seen any appreciable difference in the growth between any of the inoculated plants and those used as checks. A liberal amount of

water has regularly been applied to the plants. When the water was cut off for two or three days, the ones inoculated with *Rhizoctonia* showed less vigor. Four months from inoculation the pots inoculated with *Marasmius* produced the fruiting stage of the fungus; at the same time the cane plants were among the tallest and most vigorous ones. * * *

All the plants in the last experiment were later taken out of the pots and their root systems examined. It was apparent that the roots from the plants infected with *Rhizoctonia* were fewer in number and that many of the longer roots were brittle and decayed; the same was noticed where *Pythium* was applied to the soil; in the case of *Marasmius,* although the fungus mycelium was plainly visible in amongst the soil particles, yet the roots did not show as much decay as in the first two; the same was true with the *Odontia* and *Trichoderma* infected plants. The roots of the check plants were normal. The plants were then set out in the field. All of them made a uniform growth with the exception of a larger number of dead lower leaves being present on those which were prviously infected with *Rhizoctonia.*

At maturity the cane, all of which made a very good stand, was cut and allowed to ratoon. In the ratoons an unevenness of growth in the center of the plot was observed. This unevenness was no doubt due to soil conditions, as the effect of the previous inoculations were entirely lost during the first season of growth after the transplanting to a new location. In this small plot of cane there became evident a stunting of the cane in a central area, a phenomenon which is not unusual in cane fields. In this particular case, the uneven stand in the cane was evidently due to a very compact soil, which became more so in the center of the plot during a season of heavy rainfall.

In order to make close observation of the relation of the above-mentioned fungi to root decay of cane a series of moist chamber inoculations were made as follows: Seed pieces of cane containing one or two buds were sterilized in a solution of 1 : 1000 bichloride of mercury and placed in sterilized and moist glass jars. Cultures of *Rhizoctonia, Marasmius,* and *Pythium* were placed on the cane seed and the jars were covered with glass. *Rhizoctonia* has in two weeks invaded the growing rootlets, the threads of the fungus growing on the whole length of the rootlets. Instead of being white or yellow the rootlets turned reddish brown and the smaller roots, or those which have arisen after the fungus has had time to develop its growth, did not attain any considerable length and they were abnormally brown instead of purple at the tips. Compact masses of the mycelium were plainly visible in the softened tissues of the attacked rootlets. Reisolations gave the same type of *Rhizoctonia* from these roots. *Marasmius* grew right alongside of the roots of seed on which it was placed, but there were no striking differences of any abnormal nature in appearance of these roots and the roots of seed in the check jars. Although the fungus mycelium of *Marasmius* was in contact with the roots there was no sign of decay in them. *Pythium* did not have the same injurious effect upon the roots as *Rhizoctonia* in this experiment. However, a few roots were observed to have been attacked and upon reisolation the same fungus was recovered. Experiments such as described above have been repeated several times, using different

varieties of cane, and employing other strains of *Rhizoctonia*. The results have not always been uniform, mainly due to the fact that other fungi and ferments would enter and cause decay of the seed pieces, thus preventing normal development of roots. On several other occasions the inoculum would not grow in the jars as described, due, perhaps, to an early chemical change in the seed itself.

That the condition of the seed piece in itself plays an important part in the health of the first series of roots that arise at the time of germination has been observed on several occasions. For example, in one experiment mature Otaheite seed were used in the jars, the seed being placed on one end in the bottom of the jars in about one-fourth inch of tap water. Not a single seed out of 24 germinated and the roots did not make much headway before they became arrested in growth and finally decayed. On the other hand, the same treatment when accorded to Rayada and Caledonia did not produce in them any growth-inhibitory symptoms. The seed pieces of the latter two kept sound and their roots in most of the jars attained normal lengths and were abundantly side branched. However, the seed of these two varieties if infected with the yellow-stripe disease produced many short-lived, red roots when placed in moist jars as above. Of course, the cane bud produces its own roots after a while, but during the early stages of its growth it is dependent upon the mother seed piece and its root system in order to make good growth. If the seed piece is liable to become fermented sooner, either because of its natural lack of hardiness or because it was allowed to become weak on account of too prolonged exposure between the time it was cut and the time it was set in the ground, it is quite certain that it will give weak shoots which will be short lived mainly because such seed do not produce enough and vigorous roots.

Another form of *Rhizoctonia* was found in its sclerotial stage on the lower dead leaf sheaths of cane. Kruger[1] in describing diseases of cane mentions three diseases which are associated with three distinct sterile fungi but which produce sclerotia. One of these, causing the red rot of leaf sheaths and stalks, is *Sclerotium Rolfsii,* as can be plainly seen from Kruger's colored plate XIV. Another sclerotia-producing fungus he associates with the sour rot of the leaf sheaths. This fungus, he states, produces sclerotia of light orange-yellow color, are larger and softer than the former (*Sclerotium Rolfsii*). The fungus with the orange-yellow colored sclerotia is unknown to the writer. On pages 443-447 Kruger[1] describes and illustrates a disease under the name of sclerotia disease of sugar-cane leaves. The fungus associated with the disease is most likely identical with the *Rhizoctonia* under discussion. The thin mycelium of this fungus is hardly noticed, but its gray to dark-gray and sometimes gray-brown sclerotia which are more or less rounded, concave and sometimes ridged are commonly found in damp and shaded locations on dead leaves near and sometimes on the ground. The fungus was grown in pure culture from bits of sclerotia in corn-meal agar and on green bean pods. When a pure culture of the fungus was placed in sterilized soil in pots the mycelium grew rapidly in the soil and sclerotia were formed in large numbers on the moist surfaces of the soil and the walls

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[1] W. Kruger, Das Zuckerrohr und seine Kultur. 1899, pp. 433-466.

of the pots. Pure cultures of the fungus were placed on seed cane in sterilized soil and the growth of the fungus on the young shoots and roots was observed. The shoots became reddish-brown and dry at their bases and began to dry at the tips as well. The fungus mycelium and sclerotia were adhering to the lower parts of the young cane shoots. Other seed planted at the same time and under similar conditions, but the soil in which these grew was not inoculated with the fungus, produced vigorous shoots. In order to prove whether this fungus is capable of attacking green leaves and their sheaths above ground, portions of growth of the fungus produced in culture tubes were placed on green leaves and sheaths of cane and covered with glass chimneys. The growth of the fungus on these was rather slow; it produced lesions of various sizes, the largest being one-half inch in length on one leaf. In all cases it produced one or more sclerotia which were identical with those from which the cultures were made.

Pure cultures of the same fungus were placed on young roots of cane seed placed in sterilized moist chambers. The fungus mycelium grew over the roots and it was noticed that many of the roots soon became partially brown. Upon examination it was found that the fungus has penetrated into the soft tissue of the roots, and portions of these when planted in agar gave the identical fungus upon reisolation.

Character of the Fungus.

The fungus agrees with the general characters of the form-genus *Rhizoctonia*. Stevenson in the Annual Report of the Insular Experiment Station, of 1917, page 138, describes the fungus as *Sclerotium griseum*. The fungus is, according to the description and herbarium specimens deposited by him at this laboratory, identical with the above *Rhizoctonia*. The sclerotia do not possess a distinct cortex, are not smooth and are homogenous in color throughout. When this fungus is grown in culture tubes on sterilized bean pods it presents a very similar appearance to the growth of *Rhizoctonia solani* with the exception that the latter is darker brown. Other forms of *Rhizoctonia* similar to the *Solani* type have been grown by the writer in pure culture and which were very light in color. The sclerotia of the above cane fungus are very irregular, flat and more or less loose in texture when produced in culture tubes on bean pods. Since this fungus agrees more with the form genus *Rhizoctonia* than with *Sclerotium*, the name *Rhizoctonia grisea* (n. comb.) is proposed.

Summary.

Sugar cane roots, like many other plants, are attacked by the well-known fungi belonging to the genera *Rhizoctonia* and *Pythium*.

These fungi are common in the soils of Porto Rico.

More than one form of *Rhizoctonia* has been isolated from diseased roots of cane.

A NEW VASCULAR ORGANISM IN SUGAR CANE.[1]

By J. MATZ.

In studying the internal structure of cane affected with yellow-stripe disease and cane which was free from this disease but which was affected with top rot or rather dry top, it was observed that the annular and spiral tracheides and pitted vessels in the fibro-vascular bundles, in the lower internodes of both classes of cane mentioned, were plugged with an organism consisting of spherical orange-brown colored spores embedded in a yellowish hyaline matrix. Later this same occurrence was detected in roots of cane as well. Sometimes the vessels were filled with a mass of granular protoplasm containing all stages between numerous small immature ovate bodies of various sizes and the mature, spherical, larger spores. The larger spore bodies have more or less thickened, smooth walls with an interior of a darker, orange-brown mass of granular protoplasm; are uniformly spherical in shape, but vary slightly in size; they measure from 0.014 to 0.016 millimeters in diameter. The smaller bodies, when pressed out of vessels under a cover glass, vary in size and form. They vary in size from four microns in diameter to nearly the full size of the larger spherical bodies. In form the smallest are devoid of any distinct wall and appear like an irregular dense granule; however, the larger of these possess a densely granulated small center surrounded by a hyaline mass of cytoplasm which is several times thicker than the central granular part. At this stage the small bodies, owing to the soft consistency of their outer part, are mostly oval, due to pressure they exert on each other in the interior of the vessels. The cytoplasmic hyaline layer becomes thinner and the center larger as the individual grows into maturity. The actual growth of these organisms has not been observed, as the mature spherical bodies have not germinated in several attempts made, but as the various smaller immature and the spherical mature bodies have been found in the interior of the same fibro-vascular bundles and even in the same vessels, it is only reasonable to assume that they represent different phases in the life history of one organism. In examining fibro-vascular bundles it was found that the lowest portions contained the mature spore bodies and that these diminished and the smaller ones increased in numbers towards the upper part so that at the uppermost point of their visible penetration only granular cytoplasmic masses were found. In some bundles the organism appeared only as a mass of granulated nearly hyaline cytoplasm.

The presence of this organism can be detected in cane which shows, upon splitting lengthwise or cutting crosswise, bright yellow or orange-colored, sometimes reddish fibro-vascular bundles. These are usually located in the root region of the underground portion of the stalk. The number of orange or reddish-colored bundles in the cane examined were variable. Some canes showed only three or four colored bundles and in sectioning these it was found that they were plugged with the above organism only for about two or three inches through

[1] Jour. Dept. Agr. Porto Rico, 4:41-46, 1920.

the lowest nodes and internodes. Others have been found to be infested to a larger extent; that is, the organism was present in a majority of the bundles which were orange-colored or reddish and to a height reaching the uppermost nodes. The degree of prevalence of the organism in cane is no doubt due to whether the cane has been growing in more or less infected soils and whether the seed was infected with the organism before planting.

It must be stated that the fibro-vascular bundles of cane, due to various effects, become sometimes red, vinous or brown in color. To the naked eye it is sometimes difficult to distinguish between these and those which are infested with the above organism. Moreover, bundles infested with the latter are sometimes bright red, due to a later effect of the death of the phloem. Nevertheless, many specimens have been recognized in the field as being infected with the above organism by the symptoms described in the previous paragraph, and this diagnosis proved correct later with the aid of the microscope. A homogenous, jelly-like, sometimes colored substance is sometimes found in the vessels of injured cane. This substance differs from the above organism in its lack of granulation. Gumming disease can be distinguished by its yellow exudation.

The Distribution of the Organism in Porto Rico.

The first discovery of the organism was made in the fall of 1919 in yellow-striped diseased Cavengerie cane at Bayamón; later it was found at Río Piedras in non-yellow-striped cane of a Porto Rico seedling. It was also found at Mayagüez in the varieties Otaheite and Crystalina, at Santa Rita in Rayada, near Cayey in Rayada, near San Germán in non-yellow-striped Crystalina, and near Loíza in D-109. In all of these localities cane is known to suffer from what is usually known as "root disease." In looking for the organism it was observed that it occurred in cane which showed symptoms of stunting and the tops of which were either partially or totally dry, effects which are commonly attributed to root disease.

The Relation of the Organism to the Growth of Cane.

From the mode of occurrence of the organism in cane, and the manner of its plugging the conducting vessels in the vascular system of cane it is quite natural that an interference with growth should result. At first an attempt was made to germinate the spores of the organism in water, in sugar water, in cane juice, in fermented but sterilized cane juice, and in several agars, but no germination was observed to have taken place. Spores were kept in moist cells for over six months and no germination was observed to have taken place. Portions of cane stalks which contained bundles filled with the organism in its several stages were cut and placed in moist chambers together with healthy seed pieces of Rayada cane, and after five months it was found that the roots of the Rayada cane contained many of the spherical spores of the organism. Apparently a transfer of the organism from its original seat into the healthy cane had taken place. Inoculations with bits of infested bundles into six healthy canes were made at the basal regions of the latter. The six cane stools thus inoculated show marked stunting in contrast with other uninoculated canes growing along-

side of the former. The important fact is that the organism is able to plug the free passage of the fibro-vascular system in cane, as it is found in that condition in the field.

There seems to be no mention of such a phenomenon in sugar cane in literature on the subject of cane diseases. It is apparently an organism hitherto undescribed.

No mycelium of any kind has been observed to be directly connected with any of the spore forms of the organism. The spores are free in the vessels of the host plant, and the plasmodium is limited by walls of the vessels of the host. Therefore it agrees with the characters of the family *Plasmodiophoraceae.* It differs from *P. brassicae* in that it does not form galls and that it inhabits the vascular system of its host. The spores of *P. brassicae* are smaller than in the organism of sugar cane.

Name of the Organism.

Plasmodiophora vascularum, n. sp.

Description. The spores in their advanced stage in the interior of the vessels of fibro-vascular bundles are spherical with smooth, somewhat thick hyaline walls, evenly granulated or sometimes coarsely granulated in the interior, orange yellow, sometimes slightly brown in color, measuring 0.014-0.016 millimeters in diameter. Spores are embedded in a yellowish hyaline, at length hard matrix. Plasma is composed of a mass of granular cytoplasm, later developing into individuals composed of clear, cytoplasmic variable bodies having a dense, darker, granular center.

Habitat. Mayagüez, Río Piedras and other localities, in cane fields, Porto Rico. In vascular system of sugar cane, *Saccharum officinarum* Linn.

[C. W. C.]

Common Sugar Cane, *Saccharum officinarum.**

Natural Order Gramina: nat. both Indies. This plant and its cultivation has been so long known in the West Indies, that it will be needless to say much of it. There are several species cultivated in the Island (Jamaica), which suit the various soils and climates. There are also varieties of this cane both as to size of the joints and colour; some being a yellowish white, and long jointed, others red and shorter jointed, and another sort Elephantine, with the culm thick, and knots approximate. There is also the Ribbon cane, the culm of which is curiously striped and variegated; but not much esteemed. The Otaheite and Bourbon canes are now very much cultivated, and found to be very productive.

* From Titford, Sketches towards a Hortus Botanicus Americanus, p. 37. (Published in 1811.)

SUGAR PRICES FOR THE MONTH

Ended April 15, 1921.

	96° Centrifugals		Beets	
	Per Lb.	Per Ton.	Per Lb.	Per Ton.
Mar. 17, 1921	6.265c	$125.30	No quotation.	
" 18	6.27	125.40		
" 19	6.02	120.40		
" 22	6.27	125.40		
" 28	6.265	125.30		
" 31	6.02	120.40		
Apr. 5	6.01	120.20		
" 6	6.02	120.40		
" 7	5.885	117.70		
" 8	5.7867	115.734		
" 9	5.77	115.40		
" 12	5.64	112.80		
" 14	5.63	112.60		

[D. A. M.]